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WATER.

IMPURITIES, GATHERED FROM THE AIR AND EARTH.

THE ORGANISMS THAT GROW IN IT, AND THE MODERN METHODS OF PURIFICATION.

— BY —

C. W. MOORE, M. D.,

SAN FRANCISCO.

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PREFACE.

To claim entire originality in the matter of the following pages, would be certainly to court severe criticism. We have simply gathered from the past efforts of men learned in sanitary science, the most pertinent facts, and opinions. We owe the inception of the article, and very much of the literature to those humane agents of sanitation, and of persistent efforts for the welfare of mankind, the "Sanitary Era," the "Sanitarian" of New York, and the "Sanitary News" of Chicago. All honor to them. That their efforts may be crowned with success and lasting reputation to themselves, is our sincere wish. If in this discursive essay we shall have given them the slightest aid, and furthered their efforts to procure for the people, not only pure water, but some idea of the impurities contained in ordinary drinking water, and the cause of their presence, we shall have accomplished something. It will no doubt be seen that we advocate the theory of the spontaneous generation, (from atomic union) of certain disease germs. We know that the theory has been discarded, but he who follows the tendency of modern thought and investigation, will find much to confirm him in the belief, that like the Phœnix, it will rise from its ashes. Science aided now by the wonderful power of the lens, follows organic structure to the outermost bounds of microscopic vision, and still finds organization. It is not too much to expect, that with still further power, we may yet find the atomic elements, whose union makes *life*.

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WATER.

ITS IMPURITIES, GATHERED FROM THE AIR, AND EARTH. THE ORGANISMS THAT GROW IN IT, AND THE MODERN METHODS OF PURIFICATION.

From the earliest times of which we have any historic record, the word water, (Ὕδωρ) has been symbolical of all that was pure in nature. The "water of life," of which all Christians are implored to "drink freely"; the fountains, flowing from the throne of "Vishnu," in which the devout Hindoo bathed, sacrificed his children, and on whose bosom he entrusted his dead loves; the "holy water" of the Catholic church, which is but the emblem of the worship of the sun in Aquarius, the water-bearer of the pagan mythology, *all* are evidences of the estimation of the purity of this element, so necessary to man, and whose body is composed so largely of its substance. Modern science, the iconoclast of the ages past, has taught us, and its teachings are still in their infancy, that even the purest substances contain in themselves the elements of disease and death,—and that water, the symbol of purity, has carried disease and desolation to myriads of the human race. The microscope, revealing the secrets of nature hidden from the unaided eye, has revealed in part the life history of those pathogenic germs, whose presence in the human organism gives rise to the disturbances which we call disease, and enabled us to trace to its source many an obscure affection.

It has been fondly believed that the percolation of water through soil, relieved it from any deleterious substances, and that "the old oaken bucket that hung in the well" was the symbol of the pure fluid designed by nature for the need of mankind. The algæ that covered its sides was unheeded, and the "life-giving *element*" was quaffed with gratitude to God for his

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blessing (?) while far down in its depths, the refuse from the stable and the privy, held the destructive germs that only needed the contact of atmospheric air, to become living agencies of disease.

The subject of water has been discussed for years, and able men have given it their time, their talents, and their anxious consideration; consequently we can do little more than present to our readers a *resume* of the opinions of others. The literature is so extensive, and writers are at so great variance one with another, that in the careful reading necessary to a comprehension of the whole subject, the mind becomes dazed, wandering in the labyrinth of subjects which enter into its consideration. The atmosphere which surrounds us, and without which we could not live which in reality constitutes a great part of our body is composed of hydrogen, oxygen and nitrogen. The general composition of the atmosphere is given in Miller's "Elements of Chemistry" as follows:

	VOLUMES.
Oxygen	20.61
Nitrogen	77.95
Carbonic dioxide	0.04
Aqueous vapor	1.40

It contains also traces of nitric acid, ammonia, and carbureted hydrogen. The union of two parts of hydrogen and one of oxygen makes water. Whenever the conditions are favorable for this union, water must be the result. We breathe hydrogen and oxygen, we eat nitrogen and carbon; there results water and such other components of the body as can result from the union of H. N. O. with S. Po. C. These latter are derived from the disintegration of the foods we eat. Two clouds meet in the heavens, one charged with hydrogen, the other with oxygen. The rapid union of the H. and O. causing friction of molecules makes the electric flash. The condensation of gases creates a vacuum and the surrounding air rushing in gives the thunder. The result of the union of H_2+O gives the drops (molecules) of rain. These drops falling to the earth catch the germs floating in the atmosphere and carry them into the soil. Does the percolation through the strata rob them of these germs, and from whence are they derived? Is

their birth of air, or earth, or water? Are those floating in the atmosphere but dried particles, preserving the potentialities of life, taken up from the earth, to be returned to it in some far off place? Are they the product of water alone, as taught in Egyptian schools, or are they the product of the combination of all, the result of natural law?

We will, then, divide our subject into three parts, Air, Earth, and Water, and trace if we can the germs in each.

I. AIR, AND ITS GERMS.

Upon the great problem of the source of organized microscopic corpuscles, to which organic matter owes so many of its changes, opinions are very contradictory. Neither patient observation nor profound reasoning has solved it. The fiat of the Almighty, who commanded the earth "to bring forth living things in their kind," as the simple expression of the divine will, no longer receives the sanction of reason or scientific research, since science is delving too deeply into the CAUSES of phenomena, to be swerved from its investigations by any religious, or superstitious ideas. There are those, who hold firmly the belief, that as all bodies are composed of C. H. N. O. in varying proportions, so the germs of microscopic life arise *de novo*, in the atmosphere, the earth, the water, in compliance with natural laws: Certainly this opinion involves nothing contrary or impossible; it can only be objected to on the hypothesis of some "mystical doctrine of life," some "creative power," acting on some antecedent germ. But *that* germ must have had an origin. Bearing in mind that the fundamental constituents of living things are carbon, nitrogen, hydrogen, and oxygen, we must also remember that the degree in which other constituents, such as sulphur and phosphorus, enter into the composition of organic matter, is altogether trifling when compared with the immense bulk of living tissue that is almost solely built up of these four elements in their diverse modes of combination.

In a paper read by Dr. Hamilton before the International Medical Congress, and reported in the Medical *Record*, occurs this sentence: "In a word, the de-

privation of oxygen, either directly, by oxidation of another substance capable of attracting and retaining it, by the loss of hydrogen, by the subtraction or substitution of elemental or approximate radicals we can *exclude or arrest development, or totally destroy bacteria.*" In examining the dust of the air, we do not by any means detect *all* the microscopic bodies, whose existence is attested by changes in organic matter. We cannot declare that because they are not within the power of the lens, that others do not exist; indeed, it is a fair presumption that those which we *do* see, are developed organisms from smaller, and those from still smaller germs, which are forever hidden from microscopic vision. The primitive germs of life can only be pursued by the mind's eye, in perpetually dwindling dimensions, till imagination fails, and we realize that far, far beyond the remotest limits of human conception, the sublime work of primal organization reaches. The theory of life from antecedent life, begins where vision ends; the theory of life from the union of primitive elements, begins in the realms of the infinite and unknown.

Science may declare that that which is unseen; which is beyoud human vision and conception, is a myth, upon which can be based no rational argument; *but what then becomes of the God men worship?*

> "Pavilioned high he sits in darkness
> To *Gods* unknown, rules through radiance."

Inconceivable and incomprehensible, we yet call upon Him as the arbiter and originator of human destinies. Shall we ignore His works, because our finite minds cannot comprehend His *infinite* workings? Is there not more divine power expressed in the genesis of organisms out of primeval essence, than in any special act of the creation of a human being, with all the imperfections of the lower order of the brute kingdom inherent in his organism?

The air, then, is the carrier of the myriads of microscopic germs, which have so large an influence in the production of human maladies. They lie in wait for opportunity to exercise their baneful purposes, needing only heat and moisture, or

any form of decaying or putrefying substances for fructification. The rain which purifies the atmosphere, deposits them on the earth and in the streams, lakes and ponds. For, though floating in the air, and not living, they retain the potentiality of manifesting life, and in order that this may pass into actuality, the first requisite is water, to restore that possibility of molecular re-arrangement, of which the absence of water has deprived them, and without which life is impossible. Surgeons recognize the danger of allowing atmospheric air to penetrate into wounds or the interior of the human organism, lest it be loaded with pathogenic germs. Modern science has made no more important acquisition, than the knowledge of the action of these vibrios and bacteria; agents of putrefaction and destruction.

Not only in the human organization do these micro-organisms of the air play their destructive part. They are, perhaps, the sole agents of fermentation in all substances; multiplying with inconceivable rapidity. It has been estimated that a single cubic inch of space will contain 8,000,000,000,000 germs of average size. They increase by fission, at the rate of one division every hour. Hence a single one becomes the parent of 16,000,000 every 24 hours, and the causative parent of 32,000,000 in that length of time. A very interesting investigation has been instituted near Paris for estimating the microbes in atmospheric air, and an ingenious trap continually set to catch them. A cubic metre of air in the laboratory is found to contain on an average 530 microbes, while a cubic metre of air in the central part of the city contains 10,000; in the sewers 36,000, in old houses 40,000, and 70,000 in the old Hospital of Pitie, of Paris.

Bacteria are found everywhere. They fill the air, the earth, the water. They enter into the composition of the food we eat. They are present at our birth, accompany us through life, and at death claim our bodies as their proper reward for a life of service and watchfulness. There is no substance in which they are not present, except oils, metals and acids. *Thousands* find room in a single drop of water, and *mathematics* staggers in the effort to compute their

weight. And yet. they have their uses in the economy of nature. They decompose organic substances into inorganic and gases. They keep up the cycle of nature, and the soil could not exist without them. Sole agents of fermentation, their absence would deprive us of all fermented food or drink. In human bodies, they aid in the processes of fermentation necessary to the disintegration of foods. Life resists or escapes them, but nothing can contest with them its desertion. Death is their laboratory; there the lowest of created things work out the eternal drama of organic existence.

We have spoken only of bacteria. They are the most harmless of the host of germs which fill the air, earth and water, and which work evil in the human organism—and although greatest in number, yet give place, and are perhaps devoured by the virulent bacilli, with which, and others of like character, we have to speak hereafter, and which are called pathogenic, (disease-bearing) by scientists. These latter are they which are present in different forms, in every different disease which afflicts the human species. The microbe present in small-pox, diphtheria, yellow fever, typhoid, measles, scarlatina, etc., each bears its own distinctive feature, and marks the character of the disease. What better proof could be needed for the theory of generation, from chemical, or atomic union?

The most discordant opinions have always existed as to the nature of *Bacteria*. Among naturalists there seems to be four different views concerning them: (1) That they are organisms of the lowest grade, having an individuality of their own, as conjectured by Ehrenburg. (2) That they are of the nature of spores, produced from some of the simplest microscopic fungi. (3) That they represent a stage in the existence of certain algæ, intermediate between *Palmella* and *Oscillatoriæ*. (4) Or lastly, that they are the first and most common manifestation of newly evolved specks of living matter, capable of developing into other forms. The most reasonable theory is *that they are neither* animal or vegetable, but *developmental matter.* Bacteria vary considerably in size

and in their movements. The size differs in accordance with the putrescent character of their pabulum and the amount of heat. They are, in their most common form, mere dots, or straight rod-like bodies, varying in length from $\frac{1}{15000}''$ to $\frac{1}{20000}''$ of an inch, and present a line in the middle, dividing them into two parts. Their movement is an irregularly-rotating character. All gradations exist between movements, which stamp them as living things, and mere oscillations, the presence of which make us doubtful as to whether or not we have to do with living organisms. But bacteria only constitute one variety of the lower forms of life, met with in the air, earth and water. Only because they are the most common and ubiquitous, we give them prominence.

Intermixed with these bacteria, in the cultures from air, earth, or water, are other forms, bi-segmented, less cylindrical in shape, and instead of being rigid, having flexible joints. We find straight, necklace like rows, composed of from two to fifteen or more bead-shaped bodies, which exhibit a slow, vibratile movement. Not unfrequently we find organisms similar to the yeast fungus. These are the *torulæ*. Of the larger organisms, perhaps the development of these smaller bodies, we shall speak more fully hereafter. Davigne has described bodies met with in atmospheric air, closely resembling *vibriones*. These are the organisms met with in the blood of animals suffering from *malignant pustule*. They exhibit close affinities with the algæ known as *oscillatoriæ*, and are closely allied to the *Leptothrix* or *fungus* spores. Of the great variety of forms met with in the air, many if not all, are found in the earth and water, carried there by the rain, and will be described under their proper heading. We have in this connection to describe only the active agents in disease, in the form of bacilli met with in cultures of atmospheric air. At the present time there are three forms of *bacilli*, well known to cultivators. The *comma bacilli* of cholera, discovered by Koch; Denike's bacilli; and the one discovered by Finkler. These forms are so much *alike that* only careful cultivation in gelatine enables

us to detect the difference. The cholera bacilli grows in a peculiar funnel-like shape.

There are also the staphylococcus pyogenus, aureus, citrus and albus (white, orange, and lemon) whose differentiation can only be accomplished by careful culture and development. These are the germs met with in pus formation, the S. pyogenus being identical with Pasteur's *microbe en chapelet.* It is very easy to demonstrate the presence of micro-organisms in the air. It is only necessary to place a slice of potato, a piece of wet bread, some chicken soup, or some gelatine in a warm place. The germs whose pabulum is found in either, will fall on it, and in a few hours, colonies of the different forms will be produced. They reproduce at the rate of from 20,000 to 30,000 a minute. The same rule holds in disease; certain forms are found in cholera, others in small-pox, consumption, measles, etc., yet it still remains a matter of doubt if these germs are not a *product* of these diseases.

The whole question seems to be limited to the fact of the interchange between the different forms of micro-organisms, whether they are developed, one from another, and whether the innocent can take on virulence. If, as Nageli claimed, they are but variations of but one or a few species, so that at one time they may act as beneficent agents in organic fermentation, and at another produce typhoid or other diseases, then investigation, and attempts to destroy them are futile. But if they are specific organisms having each its peculiar function, then the question arises as to how we are to destroy the virulent, and preserve the beneficent.

If they are the product of certain chemical decompositions, the *effect*, and not the *cause*, then the object will be to prevent such chemical unions as shall cause their genesis. Dr. Semmola, in an address before the Ninth Medical Congress, said: "The error of the day is bacteriology, considered as a key to all pathology. Doctors conclude that microbes are the *cause of disease, whereas* in many cases they are the *effects. The experiments* made have not given any *satisfactory results,* except in carbuncle and tuber-

culosis. To conclude that this or that microbe is the cause of any disease, is to ignore the experimental method, since we should have not only to know that the microbe existed, but the condition (chemical) of the blood necessary to the culture of that particular microbe, and science tells us that, for the present, this is a problem we cannot solve. It has not yet been demonstrated, in what measure microbes are the causes of disease, nor the condition of their genesis." An able writer on bacteriology says: "I believe that true scientific caution imposes careful sifting of evidence, before the discovery of a pathogenic microbic causation is accepted as a fact,

Haller held that all kinds of germs, big and little—moulds, ferments, bacteria—were convertible one into another. Zurn says that "micrococci are only stages of development of moulds. Growitz, by changing the injection of *aspergillus*, from acid to alkaline culture, converted innocent parasites into dangerous. Koch and Gaffky, on the other hand, hold to the specific character of germs, and deny their interchange. Billroth declares that the different forms depend on variation of soil, and Warming considers them as different stages in the development of the same species. Klebs accepts this view, with the reservation that "certain forms occur preferably in form of bacilli, others of micrococci."

Buchner, claims to have observed under continual cultivation of the innocent bacillus of hay infusion, its gradual conversion into the deadly milzbrand bacillus, and that its reversion was not, as claimed by Pasteur, an attenuation, but an actual transformation. Koch indeed seemed to prove that Buchner was experimenting with two distinct species, and Prazmowski in 1884, confirmed this by his investigations.

But those who have worked much at the microscopic investigation of the organisms met with in cultures of atmospheric air, must doubt whether there is any break in the continuity of that developmental series which commences with the mere speck of living matter, and thence proceeds through such forms as *Bacterium*, the *Vibrio*, the Leptothrix, and the *Bacilli*. Not that this invariably occurs, but as som

Bacteria commence their visible existence as plastide particles, so *Vibriones* are but the developed representatives of certain *Bacteria*. So the filiments of *Leptothrix* grow from *Vibriones*, and become themselves developed into fungus filiments, which may produce spores, each capable of developing into some higher organisms. It is also an undoubted fact, though perhaps not always admitted, that *Torulæ cells* and other fungus germs may originate as minutest visible specks, and develop into fungus spores, previous to the formation of fungus mycelium. So it seems certain that an organism may pass through the *Bacterium* and *Vibrio* stage, and develop into a *Leptothrix*, which in its turn, may give rise to a fungus producing large and definite "spores."

We dwell thus at length upon these debatable points, for the reason that in these "beginnings of life" lie the secret of germ diseases. Atmospheric germs may be, and undoubtedly are, only the dried germs, having their genesis in earth or water, and, carried in the air, wafted from place to place, fructify wherever the elements favorable to their growth are present. This does not invalidate the theory of the production of germs in the human organism, *sua sponte* whenever the elements of their genesis are sufficient to produce them; or that they may not arise in earth or water from the same elementary substances. Whatever their origin or nature, they will be found at last, with the higher organism developed from them, to be the inhabitants of water, and to affect the health of mankind through that element. As a necessary introduction to our subject, we must speak further of some forms of microscopic life, perhaps belonging neither to air, earth, or water, but yet necessary for an understanding of the position that they hold in regard to human health.

These micro-organisms whether of the air, or the result of archibiosis, have each a selective seat of their labors. For instance, the germs of erysipelas are deposited upon the epidermis at some break of the surface; they multiply in a direction opposite to the *lymph currents. They* are never found in the blood *or in distant organs.* A peculiarity in the germ for-

mation of erysipelas, is the displacement of the bacteria first found, by myriads of wandering micrococci. It is to this contest, and the *chemical changes* created by it, that fever is due. Indeed the changes in the micro-organisms are many. First, *bacteria*, which are devoured by *staphylococci* (the agents of phlegmon) or by *steptococcus*; (gangrenous emphysema,) which is the result of another micro-organism, the bacillus which produces, or is produced by, the decomposition of organic matter. While one form of *staphylococci* multiply without entering the lymph vessels, the *streptococci* enter and follow their course. The micrococci of gonorrhœa penetrate the protoplasm of the urethral cells, and are distributed to the bladder, rectum and uterus. The *bacillus tuberculosis* has its seat generally in the lungs, yet may also be found in distant organs. The typhoid bacilli of the intestines may penetrate the mucous membrane, and accumulate in the spleen. The dumb-bell bacillus of diphtheria, which produces deep and extensive layers of false membrane in the fauces, catches the myriads of other organisms in the air, and produces a confusion of colonies of micro-organisms. The bacilli of tubercle, of syphillis, leprosy and glanders, have each the soil of their genesis, or selection. Each micro-organism bears its own distinctive character; each is evolved from the minutest speck of matter. Some forms prey upon and seemingly devour others *(erysipelas);* some seem to evolve higher forms of life *(bacteria, leptothrix,)* but each is the cause or the results of some change in the organic material, accompanied by chemical reactions.

"These microscopic living particles," says Dr. Frankland, "possess such an astonishing power of rapid multiplication that within a very short period of time it becomes impossible to form an opinion as to the number of original organisms from which the vast population is descended. But if these organisms be mingled with a nutritive liquid suitable for their multiplication, such as extract of meat; and if each *individual* organism be then immediately deprived of *the possibility* of movement, by adding sufficient

warmed gelatine to render the whole solid on cooling, then the several colonies or groups, thereafter produced from these isolated individuals can be distinguished with a low magnifying power, showing the number of parent organisms originally introduced, and also their several characters and kinds. For this purpose, the gelatinized nutritive mixture is poured upon a glass plate where it sets in a few minutes to a solid film. It is then carefully covered with a glass, and kept at a favorable temperature until the development is sufficiently advanced to describe and count them. The more potent varieties are the more active as ferments, and will the sooner liquefy the gelatine by decomposition, which is therefore one of the valuable tests of their quality."

To test the condition of the atmosphere in the Emergency Hospital, London, four plates of gelatin were exposed for 48 hours on the operating table, August 24 and 25, 1886. After six days' incubation in the moist chamber, from eight to twelve colonies of all kinds appeared on each square inch of surface. Most of these were mould, which grew very rapidly; some were micrococci and some bacilli. As less than twelve colonies developed to the square inch, it is probable if the plates were exposed only an hour instead of 48 hours, not more than one colony would be found on each four square inches.

A very interesting paper has appeared in the *Zeitschrift fur Hygiene*, by Fischer, on "Bacteriological Analyses performed during a Voyage to the West Indies." These included examinations of the sea-air, as to the number of germs contained therein, and the result showed that it was almost free from micro-organisms. In a great number of instances the air was quite free, even when large quantities were taken. In air collected no farther than 30 miles from land, only one germ was found in 42 litres. Between 30 and 120 miles from land, one germ only was detected in 1,522 litres; and at a greater distance than 120 miles none could be found at all. In the case of small islands the air was germ-free at even smaller distance. The amount of germs also depends on the direction of the wind.

That germs can be transported in the air for long distances is too well known to be disputed. Thus the germs of yellow fever, which has its origin in the paludal marshes of the West India Islands, are carried across the 60 miles of water to Florida, and from thence to the gulf ports, without any other known means of conveyance. Dr. Milroy says (Edinburg Trans. vol. ix p. 274) "Yellow fever constantly makes its appearance, at intervals more or less distant, in various tropical countries, quite independently of antecedent importation, just as cholera which is more diffusible and migratory than yellow fever does in Hindustan.

From the mouth of the Ganges and Bramahputra, the cholera spreads first through the neighboring countries. Smallpox, which, coming in some not well-known way from the Netherlands in 1527, first made its appearance in Mexico, and thence spread over the whole of North America. Scarlet fever, first heard of in Arabia, reached Iceland in 1827; South America in 1829; America in 1835; Greenland in 1847, and Australia in 1848. It may be true that it was carried to these latter countries by emigrants; but to the former the germs must have been transported in the atmosphere, or arisen from the same elementary combinations, in each separate district. Now the germs of whatever disease, if carried in this manner, from place to place, require, as we have said, water for the re-arrangement of their molecules. Whether this water is found in the human system, in the humid air, or in the moist earth, the one element needed, restores the quiescent life, and they begin the work of their nature. Not only this, multiplying with inconceivable rapidity, they are carried into streams or wells, whence they are again returned to the human system in the water drank. The examination of snowflakes falling in the Rocky mountains, has given some very interesting features as to the nature of the particles existing in the atmosphere. At the commencement of a storm, they were found to contain a large quantity of almost all the ordinary varieties of atmospheric particles and fragments, and in addition a considerable num-

ber of the *protococcus pluvialis*, of a beautiful green color; some unicellar organisms, which developed into a fungus mycelium, and some bodies resembling the Gonidia of Lichens. The melting of snow does not liberate the germs contained in it, but they are carried by the mountain streams into the valleys. The prevalence of "mountain fever" is found to depend upon the presence of these atmospheric germs in the water used.

The surface of the earth is covered with living things of all kinds, animal and vegetal, which are not only throwing off organic particles and fragments during their life, but are constantly undergoing processes of decay and molececular disintegration after their death. In populous cities there is constantly going on the wear and tear of organic products, epithelial casts, and debris from ill ventillated dwellings and sewers. The presence of these cast off elements and particles in the atmosphere, is one important source of contagious diseases among men and the lower animals. Air coming from sewer ventilators has been examined in its worst and best conditions. The number of micro-organisms in the former was found to be from two to six thousand per cubic metre, in the latter from six to nine hundred per metre.

Not only from earth and sewers are the germs of disease propagated. There are still other sources of contamination not less powerful, and of which little notice has been taken. The vitiated air coming from dwellings is one of the chief. Hitherto our knowledge of this, has related to the carbonic acid and moisture liberated. But this cannot account for the deleterious influence on health. It is no measure of the impurities which are directly or indirectly communicated to human beings. It is easy to estimate the amount of carbonic acid in the air, and it is a good index to the impurities communicated to it by respiration, but the chief source of the micro-organisms is the damping material used for filling up the space between the floors of houses. Prof. Carnelly of Dundee, made several analyses of this material, and found incredible pollution. His ana-

es show that, to use his own words, "there exists where in nature, not even in the neighborhood of man dwellings, a soil so highly contaminated with rogenous organic substances and their decomposi- n products, as the damping material under the ors of dwelling rooms." The amount of chloride of lium found in this material was on an average en times greater than that found in the ground der leaky cess-pools, and twelve times greater than at in the soil round a dung hill, although this soil s visibly soaked with filth. When the coarse ces of stone were separated from this material, it s found that the finer dust and sand that was left, ntained even more nitrogenous matter than human crement. "In the damping material of a single om, there was usually more excremental matter esent than in a large cess-pool." That all this filth alive with micro organisms, is shown by the ount of the products of decomposition which result om their activity. Thus, under the floor of one igle room, Emmerich found that there were more an 6 cwt. of nitric acid in the form of nitrates. He o showed that the carbonic acid in the air of rooms t shut up and empty, increased, although all other own sources of carbonic acid, such as subsoil air, ., were excluded. The chief cause of this con- mination was undoubtedly the soaking of fluids d shaking of dust through the fissures and spaces tween the boards in the floor. Often, however, e rubbish which was used as damping material was ntaminated from the beginning, having been taken om old houses, or rubbish heaps, such apparently many houses in this country are built upon.

It seems very likely that the contamination of the aterial in the floors, and perhaps elsewhere about e room, may be connected with the progressive filtration of the air with micro-organisms. nmerich's researches throw a vivid light on the anner in which this may affect the health of the habitants. The mortality from croupous pneumonia. creases from 3.5 per thousand in the better houses 6.6 in three roomed, and 12.5 in one and two- med.

It was discovered by Dr. Pavesi in Italy in 1870 that when the wind blew from the west, that an epidemic of diphtheria occurred at Ticino, a village 8 miles distant. Investigation revealed the fact that the algæ from some dried up marshes, and the diphtheritic membrane consisted of the same spores. There is no doubt that the germs of typhoid fever can be carried in the air. Incontestable proofs exist, that they may be absorbed by water, and so reach the human system.

Dr. Brouardel in an address before the International Congress, at Vienna, says "In these cases, and it is very easy to augment the list, I may remark that typhoid fever is confined to those places where the air was infected; and more, that this infected air was always moist. I do not mean to say that air can always carry the germs of disease, but that in the majority of cases, humid air is a favorable circumstance in their propagation. M. M. Chauteneuf and Widal seek to discover in the air the germs of typhoid. Their experiments. continued now for some weeks, are in effect, incomplete. They place in a ton of refuse some fecal typhoid matter, and collect the air traversing the heap, by the aid of water. It is always easy to collect the micro-organisms from refuse matter, but not so easy to isolate the typhoid bacilli. The technique is yet insufficent, but the results, so far, are sufficient to enable us to believe that we may yet arrive at scientific demonstrations. As a general statement of the subject, all the immense work of fermentations "putrifactions," and corruptions of organic matter, is effected by these micro-organism, by means of spores of the lowest order, of which the germs fill our atmosphere, the earth, or water. This is the most certain of modern acquisitions; one of the most important of those objects which have for their end, the improvement of the condition of mankind. It has cost two centuries of labor and investigation. Lowenhock in the middle of the seventeenth century was the first to reveal the wonders of the microscopic world of the air, and to conjecture its momentous functions. How much of patient labor and investigation has been employed

since, and how little of the vast empire of microscopic life has been invaded? What wonderful secrets are yet to be penetrated? Science looks ever to the beyond, perhaps because of the mysterious longing to learn the future; perhaps because it is of the same essence as spirit, in which all things must eventuate.

Murchison records many cases of typhoid arising from the exhalations from the putrid water in sewers. The exhalation from stagnant ponds or pools, has always been considered the prolific source of malarial disease. The germs that collect on the surface and sides, drying from the heat of the sun, are caught up on the wind, and carried from place to place. Whether the germs of measles, scarlatina, smallpox, etc., which may be flotant in the atmosphere, find their way into water, is yet a disputed point. There is, however, no question but that they, in common with all other germs, require heat and moisture for their fructification and propagation.

Overcrowding, and defective ventilation, not only favors the propagation of germ diseases by concentrating the emanations from the sick, but appear also to be capable of generating them *de novo*. There are many facts that show that enteric fever may arise from defective drainage, independently of any transmission from sick persons.

Just how much cosmical influences have to do with the outbreak and spread of epidemic disease, we have not yet learned, but practical observation has taught us that the environment of the human family has much to do with the power of combatting the action of disease germs. It is a well established fact that there are localities in the West, where fresh beef may be hung in the open air for weeks (without salt) and no putrifaction results. This can only be explained by the fact that moist air or rain was the element necesssary for the support of germ life. But wherever disease exists, there the cast off particles find their way to the earth, and so into water sheds, or wells. The ammonical and other exhalations arising from decomposed tissues, are all more or less soluble

in water, and, floating in the atmosphere, are carried down by rain, or even humid air. That the peculiar taste of rain water is due to the absorption of ærial gasses, any one may prove, by setting a vessel of water in the open air, protected from dust, for a few days. At the end of that time it will taste exactly like cistern water and very likely contain such germs as are usually present in it.

II.—EARTH AND ITS GERMS.

It may be interesting to briefly enumerate some of the different opinions which have been expressed by earlier writers on the subject of spontaneous generation.* Aristotle. believed that eels and other

* "Beginnings of Life," i: 2, 52.

fish were generated in the slimy mud of rivers and marshes; and that certain insects took origin from the vernal dew on plants, and that lice were engendered in the flesh of animals; that the caterpillars of certain butterflies were actually the products of the plants on which they fed. Some of these beliefs were echoed by Lucretius† and Ovid

† De Rerum Natura, lib. 5, 793.

more than 200 years later, When Ovid had described the means adopted by Deucalion and Pyrra for repeopling the world after the deluge, how the backwardly thrown stones, the bones of mother earth, grew into human beings; he thus accounts for the origin of all the lower living things:

'Cætera diversis tellus animalia formis
Sponte sua peperit, postquam vetus humor ab igne
Percaluit Solis, cœnumque udæ paludes
Intumuere æstu; fecundaque semina rerum
Vivaci nutrita solo, ceu matris in alvo,
Creverunt, faciemque aliquam cepere morando.
Sic, ubi deseruit madidos septemfluus agros
Nilus, et antiquo sua flumina reddidit alveo,
Æthereoque recens exersit sidere limus;
Plurima cultores versis animalia glebis
Inveniunt, et in his quædam modo cœpta per ipsum
Nascendi spatium, quædam imperfecta, suisque
Trunca vident numeris: et eodem corpore sæpe
Altera pars vivit, rudis est pars altera tellus.'

This passage (Metamorph. bk. i. 416—429) has *been thus translated* by Dryden:

'The rest of animals from teeming earth
Produc'd, in various forms receiv'd their birth.
The native moisture, in its close retreat
Digested by the sun's ætherial heat
As in a kindly womb, began to breed,
Then swell'd and quicken'd by the vital seed.
And some in less and some in longer space,
Were ripen'd into form and took a several face.
Thus when the Nile from Pharian fields is fled,
And seeks, with ebbing tides, his ancient bed,
The fat manure with heav'nly fire is warmed;
And crusted creatures, as in wombs, are formed;
These, when they turn the glebe, the peasants find;
Some rude, and yet unfinished in their kind.
Short of their limbs, a lame imperfect birth;
One half alive, and one of lifeless earth.'

Such an origin for various kinds of animals was also referred to bv Diodorus Siculus, and by Plutarch; the soil of Egypt, and the bed of the Nile in particular, being alluded to as the seat of these marvels. These notions as to the possibility of the evolution of organized animals out of decaying organic material survived till far into the Middle Ages. That which Aristotle had affirmed, was believed for many centuries after. The transition from the ancient to the modern view was first initiated by William Harvey, the discoverer of the circulation of the blood, who defined his views in a treatise entitled "*Exercitiones de Generatione Animalium.*" Although a disbeliever in Archibiosis, yet he still held doubts whether the "primordium" might not arise "*sponte et casu.*"

The first serious departure from the received doctrine of Aristotle, was taken by Redi, a Florentine physician, who in 1638 demonstrated that the maggots which appear in putrefying flesh were deposited by flies, and not engendered in the flesh. But even Redi inclined to the belief that parasites were produced from a modification of the substance of the animal in which they were found. In 1745, Needham, a Fellow of the Royal Society of London, affirmed "if putrefaction could engender insects, it could give origin to myriads of microscopic germs. Four years after, Buffon expounded his views on the subject of "spontaneous generation." He said "there are many living things which are produced by the aggregation of "molecules

organiques," as there are others which reproduce themselves by a constant succession of generation. Spallanzani next took up the question. He maintained that the air of our atmosphere bears with it everywhere the germs of organic forms. Still later Treviranus made known an important fact in favor of archibiosis; that the species of animalcules found in the infusions, *varied with, and seemed to depend upon the nature of the infusions themselves.* In 1809 appeared the "Philosophie Zoologique" of Lamarck, in which he expressed himself strongly in favor of the spontaneous origin of life, but only in its lowest forms, under the combined influences of heat, light, electricity and moisture. This is expressed in the following passage: "*La nature a l'aide de la chaleur, de la luminiere, de l'electricite, et de l'humidite forme des generations spontanees ou directes a l'extremite de chaque rcgne des corps vivantes, ou se trouvent les plus simples de ces corps.*"

Then followed a number of distinguished naturalists, St. Vincent, Bremser, Muller, and Burdach, all more or less in favor of archibiosis. Burdach contended that certain worms, insects, and even fish, *might* appear without ordinary parentage. After him came Pincan in 1845, who declared that he had actually watched, step by step, the origin and development of two infusoria *Monas lens*, and a *vorticilla* and also a fungus *Penicillium Glaucum.* During the first half of the present century, advocates of the opposite theory embraced many distinguished savants, among them Schwan, Schultz, and Ehrenberg. In his "Memoire sur le Developpement et la duree de la Vie des Infusoires," the latter endeavored to establish the fact that their genesis was from the egg. Schultz declared from experimentation that no organisms could be produced in a fermentable solution, if heated to the boiling point, and protected from atmospheric air, and Schwan stated the same sterility occurred when only heated air had access to the previously boiled infusion of organic matter.

Since this time the subject of 'spontaneous generation' has provoked vigorous discussion. In 1858 Pouchet communicated a paper to the Academy des

Sciences at Paris, entitled "Note sur Proto-Organisms Vegetaux et Animaux, nes spontanement dans l'air artificiel, et dans le gas oxygene." His views were repudiated by Milne Edwards, de Quatrefages, Claud Benard, Dumas and Payen. In 1853 Montegazzi published his researches on the generation of infusoria, supporting the theory of Pouchet.

Early in the following year, M. Pasteur became one of the most prominent opposers of the doctrine of archibiosis. There are still, at the present day, a few "irreconcilables," who believe that spontaneous generation may occur among the microscopic forms of organic existence. For the truth or falsity of either theory, it is not the object of this paper to contend. It is sufficient for us that these micro-organisms exist, and that some are capable of working harm to the human race, while others are not only harmless, but actually necessary for the conversion of organic into inorganic substances. To distinguish between the innocent and virulent is not always possible, even under the microscope, but so far as science has been able to discriminate, it is our province to note.

It is generally admitted that the action of micro-organisms play an important part in the change of organic into inorganic matter. The process is the joint work of a number of independent organisms having different functions; the action of one class following that of another, each carrying the process through a particular stage. First are the fungi whose main function is the oxidation of carbon; then the bacteria, embracing many families of similar structure, but endowed with different chemical properties. One class attacks nitrogenous organic matter, and liberates nitrogen in the form of ammonia; another determines the carbon in any organic matter, into inorganic carbonic, and nitric acids. Lastly, come the plants, to consume the products of the lower organisms. They decompose carbonic acid incessantly, fixing its carbon, and setting free its oxygen; similarly they decompose water, seizing upon its hydrogen and releasing its oxygen; while, lastly, *they abstract* nitrogen, either directly from the

atmosphere, or indirectly from the nitrate of ammonia which has been found therein. Plants are marvellous agents of reduction, working with the aid of the heat and light derived from the sun. But this is not all. The carbonic acid, the water, and the nitrate of ammonia are decompounded, because the carbon, the hydrogen and the nitrogen, entering into their composition, unite with oxygen to produce the various organic substances entering into the formation of plants. Reductions take place, but only, that combinations of a higher order may arise. Thus out of simplest elements is living matter continually being produced in the substance of every plant that grows—thus are the combinations resulting in the production of living matter, continually brought about, and the gulf between the non-living and the living, continually bridged. Science proclaiming with unanimous acord, from every quarter of the globe, the principle of evolution, does not yet comprehend the transition from lifelessness to life, nor the stages of transformation from the simple to complex forms. The *scientific proof* of the origin of life is yet but conjecture; but there can be but little doubt that the secret of vitality and organization, lies beyond these minute specs of living matter, for organized bodies must be the result of organizations more minute than themselves. These operations must follow in regular sequence, or they fail to do their work. It is in this constant change of pre-existent states; in the potentiality and affectibility of the minute masses of organic matter, that nature has its well being, and its perfectibility. It is the concentration of actual and potential energy, invisible, it may be, but none the less in ceaseless activity.

The myriads of germs that have their origin or their abode, in the strata of earth, are the mighty scavangers in the vital economy. The purifiers and cleansers, they seize upon stray matter, waste products of function, and unassimilable matter of all kinds, and convert them into harmless and eliminable compounds. That they are useful in effecting the *purification of sewage*, and decaying matter in the *soil, is proven by* the experiments of Frankland,

Schloessung, and others; the purification being arrested, when the soil was for a time made sterile by saturation with chloroform. The chemical assistance to these changes and modifications, is performed by the salts of the soil, alumina, potassa, lime, iron oxyd, etc., with carbon and other absorbents; their principle functions being to form new and insoluble combinations with the elements of these soluble compounds, and to convert these into elements which can be taken up by the roots of plants. Thus this ceaseless metamorphosis in nature is found everywhere. In plain, valley and mountain; things visible and invisible, great and small, are hidden in the mass, rolled up in leaves, boring into the roots and stems of plants, eating into the hardest rocks. Not content with filling the air, every inch of earth holds its teeming population of living things. If we ask of the sea—the ponds—lakes and rivers, we find the same active life ever busy in the quest of food. In the mud of the deepest sea bed, microscopic life exists, and banks of coral are built by drops of living slime, in the midst of dashing waves. You cannot lift a stone by the seaside, but you will find some living thing under it, nor turn a spadeful of earth without disturbing some little creature, which has its home and its food in the dark ground. No animal or insect but has its parasites, whose food is found in the substance of their bodies.

"Fleas have other fleas to bite 'em
And so it goes, ad infinitum,"

From the day when first our planet came from the hand of the Creator, the invisible mother has never ceased her work of production. Thousands of millions of microscopic insects make their advent each moment in air, earth, and water, and must find food to sustain their life. Think for a moment. If there were only one plant in the world to day, and it could produce but fifty seeds in a year, and could multiply unchecked, its descendants would cover the globe in nine years (Huxley). A pair of birds having four young each year, would produce *two thousand millions in fifteen years.*

We have spoken of the rapid increase in micro-

organisms. What can be the use of this terrible over crowding? Why should nature be so prolific? Because one generation furnishes food for another; each devours the other in its necessity for life, and thus the equilibrium is maintained; the weak give way to the strong; it is the "survival of the fittest."

When organic matter decays, either in animals or plants, a double process of composition and decomposition invariably occurs; the organic substances break up into simpler compounds, during which the previously locked-up forces become instrumental in bringing about new changes in other constituents of the organic matter, and the new products appear as specks of living matter, which gradually grow into *Bacteria*, *torulæ* or other simplest forms of microscopic life. Thus vital processes are transformed into chemical processes, and these again give birth to vital compounds. Fungus germs are born from their parent fluids. Though hidden from ordinary view, they become manifest when the ever varying forms of mould and mildew appear and flourish on the surface of the previously living organism. So, polluted soil undergoes such degraded and vicious decompositions, as that it may originate or propagate any germ of disease. As to cholera, this is the distinct view of Pattenkopher; and as to typhoid, he considers the ground a prominent factor. The tendency of ground pollution is to generate disturbances in the organisms of those exposed to its influence. It is during these changes, occurring in decomposing organic material, that certain poisonous substances are formed, to which has been given the name *Ptomaine*. They are found in the products of fermentation and putrifaction, and are supposed to be the result of disturbances in chemical affinities, or in the disoxidizing power of the micro-organisms, and to result in the formation of gases and waste products. Prof. Poehl says "the formation of ptomains in nature is due to the vital action of micro-organisms. As animal cells elaborate carbonic acid, urea, etc., and plant cells the vegetable alkaloids, we must naturally infer *that bacterial cells*, the product of putrefaction, elab*orate the cadaveric* alkaloids. It is no doubt due to

these cadaveric and other alkaloids that the spread of disease, by means of water, is due. Prof. Panum states that "there exists in impure fluid, *after all micro-organisms have been removed, a specific chemical substance*, capable of producing in the human system the peculiar group of symptoms belonging to the ptomaine. Fazzie and a number of others followed in the same direction, and finally, Selim demonstrated that a number of such vegetable poisons were veritable organic alkaloids. We know that putrefactions are caused by the action or death of *bacteria* and *vibriones*, and that ptomains are the result. Ptomains extracted from culture fluid of the cholera bacillus, will produce all the phenomena of cholera," proving that many, if not most of these, are soluble in water, and so are carried into streams or wells. The Second English Rivers Pollution Commission, published conclusions based on the examination of some two thousand samples of water claimed to be drinkable. They state that the admixture of even a small quantity of the infected discharges (from persons suffering from cholera or typhoid) with a large volume of drinking water is sufficient for the propagation of these diseases, among persons using such water. M. Pettinkofer declared at Munich, that there was a constant relation in typhoid, with the oscillations of subterreanean waters; the remission and exacerbations of epidemic diseases corresponding, first, to the elevations and second, to the abatement of these profound bodies of water. He concludes that in the depressions, the organic matters, abandoned in the soil, to putrefaction by the aid of solar heat, produce the germs of typhoid. M. Brouardel says "other observers publish a number of contradictory examples; I do not join in the negation of these influences. It is enough for me to believe, that while in the theory of Pettinkofer there is much of truth, the theory needs confirmation." When the subterranean waters subside, the sources or the rivers, of course, dry up, and the organic debris are directed to the base of the declivities, or the water basins. At other times typhoid fever coincides with the elevation of these subterranean waters, which, *saturating* the surface soil, empties itself into wells,

and so carry the germs of typhoid, which may remain for an indefinite time, capable of generating the disease. That emanations from soil may contaminate fluids, is proven by some experiments lately made by Prof. Vaughan of Michigan, in the house of a farmer who sold milk. He says in his report: "The house was 50 years old, the floor was nearly rotted away, and was covered by a new one; there was no cellar. The land in all directions sloped towards the house, and there was no artificial drainage. The sweepings for years had accumulated under the floors, so that a nauseating odor arose. The milk consumed by the members of the family was kept in a small closet, where they frequently went and helped themselves. There had been frequent cases of sickness, which had resulted in the death of two of their number. Dr. V. made experiments as follows. He placed fresh milk in the pantry for a short time, and then found that a large quantity of tyrotoxicon had developed in it. He took some of the earth from under the pantry floor, and placed a small quantity of it in some fresh milk; soon after which, the poison was obtained from the milk, while none could be obtained from another sample which stood by the side of the milk in which the earth had been placed. This seems to demonstrate that the soil contained either the germ, or the cadaveric alkaloid.

That the germs of typhoid fever, or the ptomaines arising from the excrement of patients may convey the disease, is well proven by hundreds of incontestable cases, and the same proof holds good, that the water conveying them into streams or wells, can also convey these soluble alkaloids, and generate the same disease.

That disease germs, having their genesis, or abode, in animals or birds, may find their way into the earth, and so into water, is well understood. Experiment and investigation has proven that many of the diseases which affect the human family have origin as parasites in the lower orders of animals; *thus the tænia echinococus* is common to hares, *dogs and* wolves, T. *Media* cornulata, to sheep *and oxen; Cœnurus cerebralis* in sheep; and some

species of *ascari* are found only on the ears of bats. The list might be indefinitely prolonged; but from whence are these germs derived? Are they the product of certain combinations of vegetable or organic decompositions, and so taken into the animal system in the act of feeding, or are they the *natural parasites* having their genesis in the chemical and physiological changes occurring in the bodies of the respective animals. If their genesis is of the earth, then their presence in the water of brooks or wells is explained. If of the animal tissues, then equally they may find their way into the streams by seepage from the saturated soil.

We know that hogs are infested with a parasite which produces in them the disease called measles, but which in the higher orders, will develop a tænia. So the *Trichina Spiralis*, met with in no other animal, is yet capable of propagation in the human species. The worst of parasites (not excepting trichina) which finds its way through earth and water into the human system is the *Tænia echinococcus*. It is properly a parasite of hares and dogs, which they throw off in their excreta, both in the egg and in the adult form, and which mingles with the water of streams and ponds. It is stated that in Iceland, where dogs and men have intimate relationship, that one-sixth of the population and twenty-eight per cent. of the dogs are found to be harboring this entozoon. It is one of the most common inhabitants of our inland ponds and forms one of the worst of internal human parasites. It is only a quarter of an inch in length in the mature adult form. Its life history has three phases: the ovum or egg, the intermediate or larval form (called hydatids), and the perfect parasites. It is a curious fact that, while the adult form will mature only in the dog, the larval type will develop and multiply in the human body, but never gets beyond this stage.

One of the joints of the adult parasite in the dog contains the sexual parts, which are capable of developing from five to six million zooids, which in their turn can produce 150,000,000 ova.

That tuberculosis has its origin in fowls has been proven by the researches of Koch and Dr. Sutton.

Ribbert, of Bonn, published a paper in the *Deutsch Med. Wock*, 1883, announcing the parasitic nature of the disease in birds, and its identity with *tuberculosis* in the human system. Cornil and P. Meginn published an article in the *Journal de l'Anatomy et de la physiologie* in 1885, entitled "Memoirs sur la tuberculose, et la Diphtherie, chez les gallinacœs," confirming the presence of the bacilli. The identity of the bacillus was established in avian and human tuberculosis still later, by Dr. Sutton. If we inquire closely into the manner of feeding farm-yard fowls, we shall find that the seeds, and other foods, are thrown upon the ground, to be picked up by them. They are constantly dropping their excrement over the same ground, so tnat the food is contaminated day by day. Wocard succeeded in inoculating tuberculosis from birds to mammals, proving its transmissibility, and this, may perhaps, be the way in which this scourge of the human race has its origin. Once the fact is proven, that the germ of this bane of civilization has its genesis in the excreta of fowls, and its proper culture ground in their tissues, then science may find means of diminishing the mortality from this source. The washings from farm-yards, carrying with them the alkaloids of tuberculous matter, find their way into adjoining wells or brooks, and so contaminate the water used for drinking purposes.

That scarlatina has its origin in cows, has of late been asserted. From the scales, and eruption on the teats, the scarlatinal germ, has been developed. Whether it arises *de novo* from any diseased, or peculiar conditions of the animal, yet remains for investigation. That it can be conveyed in milk is beyond doubt. That it may be carried by rain, from the earth, into which the germs may fall into wells and ponds is also beyond question.

Dr. Canfield, in a lecture before the Royal School of Military Engineering at Chatham, says: Mere passage over the soil does not purify water. The effluent water which goes off the land, is to all intents and *purposes Sewage.* Mr. Denton, a distinguished engineer, says: "Water collected from the surface of *cultivated lands,* and from under-drains of cultivated

lands, is always more or less polluted with the organic matter of manure, *even after subsidence in lakes or reservoirs.*

But the most frequent sources of contamination of soil, arise from privies. Dr. McCurdy in the *Sanitary Era* says, (p. 207):

There is not a city, town, or village that is not now honey-combed by them, and at this hour diggers with bended backs and sweating faces are adding to the number by tens of thousands. It is but a question of time when all our surroundings will be fully saturated; the ground air charged with virulent poisons and the ground water saturated with the germs of death. The effluvia from these vaults are like the smoke from the bottomless pit, ever ascending. Brick or stone and cement; what do they amount to? Each brick will suck up and hold at least one pint of liquid excrement; each stone absorbs the same as if a sponge. Now with a vault walled with several hundred of bricks, or many tons of porous stones, or both, which are fully saturated with vault contents, which in turn are surcharged with bacteria, bacilli, micrococci, and all the other germs possible to convey or generate disease, and as these press into the air or ground, instantly the same pores are again filled, this time may be with the discharges of cholera, typhoid, scarlet or yellow fever, diphtheria, dysentery, smallpox or measles; and so this evaporation and absorption, continue night and day, week after week, month after month, and generally year after year;—how can we be without epidemics while this order of things lasts?"

A barrel of Kerosene Oil buried ten feet under ground will, it is said, contaminate every well within a quarter of a mile, and the oil will be apparent to the taste. The accumulations of privy vaults will extend their pernicious influence even a greater distance, although the water which it affects may not indicate to the taste the presence of any impurity. Whether privy vaults are open or plastered with cement, they cannot keep the poisonous gases and substances from penetrating the surrounding soil.

Too much stress cannot be placed on the disease

lurking in all manner of human excreta, especially those of the sick. In no case is it safe to drink water which has been contaminated with thesae since it is certain poison, and will surely reproduce the parent disease.

The tendency of all seepage of water is of course towards the lowest point of land, and it may not be out of place to define the meaning of *water shed.* It is ordinarily employed to denote the area collecting the rainfall, and comprized between the highest and lowest point. Properly speaking, the water shed "is the anticlinal ridge separating one river basin from another." The highest crest line of a ridge, therefore, is a *water shed.* The lowest area in the valley, up to the water level, is the *water basin*, while the area between these may be termed the "gathering ground," or the "collecting slopes."

Thus these "water basins" may be polluted by the application of any organic manure to their gathering surface, for agricultural or other purposes, and the consequent pollution of the water derived therefrom. Organic germs and corruption of every kind are carried into lakes and ponds in vast quantities from the rotting carcasses of animals and from decaying vegetable matters and the surplus of the soil. Were it not fer the oxidizing influence of the air which converts into innoctuous forms the rotting organic matters, not only the water would be poisonous, but human life could hardly exist on the earth. It is beyond question that decomposing vegetable matter is the cause of malarial fevers, and that water can carry the germs.

It must be borne in mind that the water supply of cities though delivered through iron pipes, yet is gathered from the rain-fall upon these slopes, and stored either in natural basins (lakes or ponds) or in artificial reservoirs, from which it is drawn through gates, or directly into pipes or ditches.

As very few people have any definite idea of what the seepage from these slopes consists, and how much it may contaminate the water in the basin, we give *the definition:* "Seepage (or sewage) consists of any *refuse from human* habitations, that may affect the

public health. Sewage is a complex liquid; a large proportion of its most offensive matters is of course human excrement, discharged from water-closets and privies, and also urine; but mixed with this there is the water from kitchens, containing vegetable and other refuse, and that from wash-houses, containing soap, and animal matter from soiled linen. Denton says: "The water used for personal ablution, and for washing the clothes we wear, and the utensils used in cooking, have a material influence on our sanitary condition. There is also the drainage from stables and cow-houses, and from slaughter-houses, containing animal and vegetable offal. Where privies and cess-pools are not connected with sewers there is a still larger proportion of human refuse. It is in fact, water mixed with a vast variety of matters, some in solution, and some in suspension. It is in this seepage filth that the decomposition occurs, which is productive of so much disease. It is not only on the surface of the soil that this takes place; wherever the conditions of heat, moisture and the products of decomposition are present, there the bacteria and bacilli propagate, or have their genesis.

By means of experimental researches, *J. Soyka* has demonstrated that through the capillary currents, existing in the soil, bacteria may be carried upward; he used for his investigations glass tubes of about 1.5 cm. clear width and of different lengths, closed loosely at the under end by a pad of glass wool and filled with sand of differently sized grain; these tubes were fixed appropriately in wider vessels by means of a cork, and the outer vessels, after previous sterilization of the whole apparatus, were made the recipients of a layer of a fluid infected with certain bacteria, so as to have the tubes with their under ends immersed in the fluid. It then appeared that with the ascension of the fluid in the interior tube, caused by the capillarity of the bottom, the bacteria are being conducted upward, and that, consequently, the soil is *not* endowed with the quality of a filter, through which the bacteria would be arrested. In opposition to the author's opinion, *A. Pfeiffer* asserted that the ascension of the fluid was not dependent on the capillary

cavities of the bottom, but was caused by the selection of narrow experimental tubes, and was therefore effected by the capiliary attraction of the glass wall only. *J. Soyka* refutes this and several other objections, demonstrating by new experiments made with glass tubes of 50 mm clear width, that indeed the ascensionon of the fluid is dependent on the capillary cavities of the bottom, and that also, as might be expected, the grain size of the sand, which is being used, has a determining influence on the velocity, of ascension, respectively on the attainable height, and that, besides, the influence of the kind of bacteria, used on thesc experiments, makes itself felt inasmuch as in fluids, rendered slimy by the bacteria, a slower ascension was to be noted than in fluids of thinner consistence.

WATER.

We come now to the subject of water, on which sanitarians are intently engaged. The public demand, stimulated, during the past year, by their efforts, will not be satisfied with a partial realization of their desires, but require of their local governments such methods of purification as shall give them a perfectly pure fluid. In answer to this demand, the public water works of this country were increased nearly fifty per cent. during the past two years, and now supply over *fourteen hundred* cities and towns.

But this great agitation for pure water has brought everywhere into public view the defects and dangers of those very sources from which the purest public water supplies are sought. Scientific analysis applied to all such waters has revealed startling degrees of impurity.

The progressive deterioration inevitable to all aqueduct waters, surface supplies, and even wells and springs in the midst of growing population, has been pointed out by eminent examples, such as the Cochituate water of Boston and the Croton of New York, which are now no longer the boast and satisfaction of those cities, but on the contrary a troublous sanitary problem.

Terrible examples of the secret contamination of *unsuspected wells,* resulting in widespread pestilence,

have arrested public attention and excited salutary suspicion and alarm.

CHLORINE.

Good water on an average contains perhaps from 0.4 to 1.0 grain of chlorine per gallon. If a water contains more than this amount it is a strong indication that it has received pollution from cesspools, sink-drains, or the excreta of animals, all of which are highly charged with salt. But some localities, especially those near the sea, contain more than the *general* average, and there being no other indications of impurity, it would be unwise to condemn it. On the other hand, it would be equally unwise to pronounce a water safe if it contains less than the average amount of chlorine; because waters very badly polluted with vegetable matter alone, are deficient in chlorine. However, when chlorine is deficient, it is certain that there is no contamination from animal matter.

It is possible for waters to contain salt that has come from filth, without containing the filth itself. When this is the case, one of two conditions exists: it may be indicative of a past pollution, or a warning of coming danger. Filth that had previously found access to the well may have undergone complete decomposition, while the salt remains; of filth may be so far from the well that nothing but salt itself is washed through the intervening earth into it. Both conditions render the well unsafe, for in the one case another inflow of filth is liable to occur; in the other, the soil may soon become too fully charged with it to retain it at all.

AMMONIA.

A minute and variable quantity of ammonia exists in the atmosphere. From this source rain water receives it, which contains less than 0.5 part per million. The earth, in turn, absorbs it from rain water, while some of it is destroyed by oxidation, so that rivers seldom contain more than 0.1 part per million, and perfectly pure spring or well water contains only a mere trace.

Of course, all the ammonia, as such, that any natural water might ever contain, is perfectly harmless.

The decay of organic matter produces ammonia, and importance is attached to the latter only as it indicates the existence of the former.

In the laboratory two kinds of ammonia are recognized, " free" and " albuminoid." Free ammonia is that which has resulted naturally from the decay of orgnic matter contained in the water, and, other things being equal, shows how extensively such decomposision is going on.

Albuminoid ammonia is that which results from hastening decomposition artificially. It measures the amount of organic matter present which may decay, and is, simply what would be produced, naturally, in the course of time.

It has been found that, generally, whenever a certain amount of free ammonia occurs in water, an excess of albuminoid ammonia is also sure to exist. So it is pretty safe to conclude that such water is polluted. Says an authority: "When the free ammonia exceeds 0.08 part per million, it almost invariably proceeds from the fermentation of urea into carbonate of ammonia, and is a sign that the water in question consists of diluted urine in a very recent condition. In these instances the water will likewise be found to be loaded with chlorides." Of course there are exceptons. Some waters, organicly pure, naturally contain much free ammonia, while others, that are badly polluted with vegetable matter, may contain sometimes much less than 0.1 part per million. In such cases the determination of albuminoid ammonia is indispensable to the detection of pollution.

NITRATES AND NITRITES.

The presence of these salts is a bad indication only so far as they have resulted from the oxidation of nitrogenous organic matter. Their occurrence, taken alone, teaches nothing positive; taken in connection with other evidence, it gives valuable information. But, as a rule, the presence of more than a trace of either salt is a strong indication of pollution from *animal matter.* However, some pure waters contain *nitrates which* they have dissolved from the earth *and rocks of* the locality.

A little nitric acid exists in the atmosphere, coming probably from the oxidation of ammonia. Hence rain water contains it. On the other hand, some very bad waters, especially those contaminated with vegetable matter, do not contain a trace.

The importance that is to be attached to distinguishing whether the nitrogen compound is a nitrate or nitrite, is this, generally: If nitrites occur, it would seem to show that the polution is recent, or its source very near. If nitrates alone exists, it would be infered that there has been time enough for complete oxidation, and hence the polution is of longer standing, or its source far away. It sometimes happens that the occurrence of nitrates indicates the approach of pollution instead of showing actual or past pollution. This is especially the case when there is no other evidence of impurity, unless it is that of chlorine, for the soil about a well sometimes acts as a filter to retain deleterious matter, until it becomes so saturated with filth that it can no longer accomplish this.

HARD WATER—LIME.

Dr. N. B. Sizer, in an essay on Drinking Water, says: In regard to the use of hard water, if we consider for a moment the functions subserved in our economy by the water we drink, we shall see very clearly why hard water does us harm. Leaving out of the account the water lost by transpiration through the lungs and skin, we may state, in a general way that the use of water is to wash the blood clean—that is, to dissolve and carry out of the blood the waste materials picked up by the blood, which are soluble in water. Now, we all know that a liquid can only dissolve a certain proportion of any solid; therefore, if we preoccupy our potable water with from 10 to 50 grs. per gallon of various salines, it is easy to see that we impair its power of dissolving and removing from the blood the proper amount of waste material; and also that, if it be thus overloaded with dissolved salines, the water will be very apt, like an exhausted laborer, to drop part of the load the first chance it gets. Such deposits actually occur, in very important

and delicate organs; notably the kidneys, urethra and bladder, forming the diseases so common in limewater districts—"gravel," "stone in the bladder," or "urinary calculus."

The element of hardness in water is usually bicarbonate of lime; that is, some nine parts of lime to fourteen parts of carbonic acid. This combination is soluble in water.

Another important point, is the effect produced by the alkaline nature of hard water. The reaction of the urine in health is acid, and in many diseases, alkaline—the alkalinity being also easily produced by taking alkaline medicines, hard water also producing this effect. Accordingly we find that when the water is particularly hard, physicians find it necessary to put patients suffering from digestive, intestinal and renal diseases, upon distilled water as a drink, exclusively, and with the happiest effects.

LEAD.

One of the most common, and at the same time delterious agents in water, is lead. When the metal or its oxyds is brought in contact with water, the gases (H_2+O+Co_2) convert it into lead hydrate, or carbonate. If there be much carbonic acid gas present, a carbonate of lead would be formed, and this, being soluble in water, would prove dangerous in the household. The presence of a small amount of ammonia, renders it more soluble. This is generally (but not alway) counteracted by the presence of lime, and the alkaline sulphates. There is then formed a thin insoluble coating of lead suboxyd, or sulphate, which prevents the solution of the metallic oxyd. Upon this chemical reaction rests the immunity from lead contamination (Curtman). Some very nice experiments have been lately instituted to prove that lead salts are an important factor in plant growth. The lichens and alzæ, with other fresh water growths, incinerated, and tested for lead have in every instance been found to possess the mineral in some degree. So that any excess, beyond that required by nature, must depend, for its climinination upon the lime and sulphates present in the water. Thus nature, by its

own chemical processes, does much to render water pure.

Of the capability of water for the transmission of disease germs we have already spoken, yet we desire to add a few instances confirmatory of the facts.

Since Eberth published the results of his investigations, in 1883, upon the etiology of typhoid fever, and carefully described the micro-organism which is the etiological factor in the propagation of this disease, numerous pathologists have followed in the same line of work, adding to the life-history of the germ, and confirming by personal observations the conclusions of Eberth, that there is a a specific and demonstrable agent in each and every case of typhoid fever, and the bacillus typhosus may now be looked upon as an accepted fact.

Chantamesse and Vidal on three occasions discovered these organisms in the water of the Seine, which was stored in a reservoir for drinking purposes. They also demonstrated the presence of this bacillus in the water of a well at Pierrefonds, not far from Paris, which had caused an outbreak of fever; and Thoinot, last March, took water from the reeervoir of Villejuif, and without difficulty obtained the characteristic bacllus of Eberth and Gaffky. Hochsetter examined the soda water from different manufacturers and found all to be extraordinarily rich in bacteria. The calculation was made that in one cubic centimetre of this water there were between 73,000 and 75,000 bacteria. He impregnated the water with pathogenic bacteria and found the duration of their existence varied greatly, from a few hours up to several weeks. The typhoid bacillus retaining its active properties from five to seven days. Seitz found this microbe in the urine of typhoid patients—a fact of deep practical interest—and we would urge the necessity for a thorough disinfection of the discharges from the bladder as well as those from the bowels.

WELL WATER.

By far the most pernicious sources of impure water are the wells scattered throughout the land. The more populous the country becomes, the more will be

the danger, naturally, for in this case the surface of the earth is honeycombed by privy vaults; by ground filled in with all manner of refuse, by the seepage from stables and cow sheds, and by house refuse, continued for years. The spread of typhoid and malarial fevers has often been traced to the use of water from some particular well. It is a fallacy to believe that because water has percolated through the earth, or arises from some subterranean source, it is free from bacteria. Experiance and chemical analysis has proven that certain elements of disease, especially typhoid, are dissolved in the fluid; and so percolate with it into wells and springs. That the water looks clear and bright is no evidence of its purity. Filtraation even does not seem capable of eliminating the poisonous matter, since water has been filtered through thick beds of sand or gravel, coming out clear, but yet capable of producing disease. We admit that to a certain extent, and in certain kinds of stata, the process of filtration tends to render it less hurtful; still, after a time this purifying power is lost (the water not being cotinuously used in large quantities), and the sewage or impurites enter and saturate the whole well. The length of time that a well may retain disease germs must of course depend on the amount of surface filth that is allowed to accumulate, but after that source has been removed, years may elapse and the water retain its poisonous quality.

In an article from *Zietschrift fur Hygiene* in *Sanitary Record*), on the conditions of the existence of the different kinds of bacteria in well water, is the following: Microbes are found in the water from pumps, from artesian wells, in spring water, etc. After having drawn a considerable quantity of water from a well, a perceptable decrease of bacteria may be observed. This diminution justifies the conclusion that the suterranean water which feeds the wells is up to a certain distnce free of bacteria, and that the layers of soil from which the water percolates form a filter *impervious to bacteria*. Other observations support *this view. The* practical conclusions arrived at from *facts are:* In order that the water of a well

may contain the least possible quantity of bacteria the walls of the wells must be of absolutly impermeable material; the well ought to be fed by deep subsoil water, and be continually and regularly used.

In the same article it is stated: In recapitulating the results of his investigations, Bolton arrives at the following practical conclusions: The infection of well water by pathogenous bacteria originates more frequently during its percolation through the deeper strata, and in subsoil water, than from and at the surface of the ground. The bacteria do not infest and render dangerous the well for a long period, as they themselves perish after a few weeks. The spores of longer vitality can only be eliminated by continuous emptying of the wells.

A clear water is not necessarily a pure water, nor is it necessarily a purer water than another which may be cloudy or turbid from suspended matters, for the substances which are held in suspension in a water, and are more or less visable to the unaided eye, are not those that give it its dangerous qualities. The organic matters that are dangerous to health are in solution, or if particulate, are so minute as to defy the powers of the microscope, and may be present in abundance in a water that is clear and brilliant from having undergone the most perfect natural filtration.

TYPHOID FEVER IN WELLS.

The poison of typhoid fever, indigenous in most of our cities, and probably disceminated in most instances by the water supply, is one of these dangerous invisible essences. Its presence is probable in all well waters derived from areas that have long been settled. It is the product of a foul soil or of one specifically contaminated by the excreta of an indivdual suffering from the disease. The wells of cities furnish a water that is of a doubtful quality from the very locality of its derivation. Sometimes typhoid fever is endemic in a city by the contamination of its general supply. On the sanitary knowledge of the present day. Newark will never be free from this fever so long as the sewage of Patterson forms part of its water supply. The turbid water of the Potomac is free from

without queston, but it is also imperative for the health of those using it, that frequent analysis should be made, and that some means should be used for its purification, or that a new well should be sunk so deep and in such a situation that no surface filth can percolate into it.

RAIN WATER.

To ordinary observers, it would naturally be supposed that rain water would be perfectly pure. The contrary, however, is the fact. When the drops of water are formed in the atmosphere from condensation of vapor or gases, small amounts of nirite and nitrate of ammonia(Cl. H.) are formed and dissolved in each drop. There is also in the atmosphere carbonic acid derived from the combustion of vast quantities of fuel, and from the respiration of men and animals, oxygen, azone, nitrogen, and carburetted hydrogen. Besides these there is also a vast amount of ercremental dust, the fine particles of which, in windy weather become suspended in the air, to the extent, over a large territory, of hundreds of tons, and remains there until washed out by the falling rain. We say nothing of the invisible germs of disease which are also craried in the air, as we have already spoken of them. Nevertheless they form one of the most dangerous impurities of rain water. Thus rain is in reality water which has washed a dirty atmosphere. Says the report of the Royal Commission on the Domestic Water Supply of Great Britain: Rain water is laden with mineral and excrementitous dust, zymotic germs, and the products of animal decay and putrefaction. A half pint of rain water condenses out of about 3,373 cubic feet of air, and thus, *in drinking a tumbler of water, impurities which would only gain access to the lungs in about eight days, may be swallowed at once.* In a lecture delivered by John Berkenbine before the Franklin Institute February 4, 1887, he says (Sanitarian, Aug., 1887), let us consider the precipitation upon an acre and a square mile:

In a square acre there are .....43,560 square feet.
" " *mile* " (5,280×5,280)=27,878,400 " "

Therefore, each foot of rain which falls upon these areas is equivalent in volume to—

43,560 cubic feet, or 325,829 gallons of water per acre, and
27,878,460 " " " 208,530,431 " " " " square mile.

Now, in round numbers, thirty-two cubic feet of water under ordinary conditions and temperature, weigh one net ton (2,000 pounds), and thirty-six cubic feet weigh one gross ton (2,240 pounds). On this basis, the weight of water can be readily calculated; however, as the usual method of reporting the rainfall is in inches and not in feet, we may first bring the above figures to this base.

For each inch in depth of rain, the figures per acre and per square mile are as follows:

	Volume.	*Weight.*
Per acre,	3,630 cubic feet, or 27,152 gallons—	100.8 gross tons; [113.4 net tons.]
Per sq. mile,	2.323 cu. fe., or 17,377,536 gals—	64,533⅓ gross tons. [72,600 net tons.]

The weight and volume of the average amount of rain which annually falls on the city of Philadelphia is as follows:

Volume.

For the year, 13,580,327,043 cubic feet, or 101,603,286,282 gallons.

Weight.

377,314,640 gross tons, or 424,478,970 net tons.

On the roofs of dwellings, this rain water, which is after all, the only source of our water supply, meets with soot and dust. After it has fallen on the earth it hastens to enter it, but during its short passage through the sod, it takes up great cargoes of impurities, the products of decayed vegetable substances, and the excrement and filth of civilization, which it carries down into wells, streams and rivers. The rain in falling not only collects impurities, but also the mineral elements of the earth, salt, magnesia, silica, lime, etc., which dissolve it. Nearer the earth, coal and tar particles, sulphur, gases, and effluvia enter into it; as factors of impurity.

It is true that, expressed in figures, the impurities in rain water do not form a very striking amount—*about 5* grains in 1,000,000—but when we take into account the quantity of rain water falling, which in

rain of one inch upon one square mile amounts to about 71,900 tons, we obtain tons of impurities. To show how many elements there are in rain water, it is sufficient to say that this amount of rain would carry down 915 pounds of salt and one-sixth of a grain of silver. This, in its turn, is liable to be further contaminated by soakings or infiltrations from cesspools and privies, and also on a larger scale by the land drainage, sewage and refuse of towns, which flow into our rivers, by dead fish and animals and decomposing weeds.

RIVERS, LAKES, AND PONDS.

The sources of the water supply of any city or town, where water is generally furnished the inhabitants through pipes, must come through lakes and rivers, or from large natural or artificial reservoirs. That these must receive their water, from water sheds, or from springs is self evident. The larger source of supply is from rivers or creeks. That these waters must receive the debris from not only the banks, but from the dwellings thereon, is beyond question. The impurities then, will consist chiefly in the excess of the decomposed materials which cannot be converted to plant use, and of the excrement and refuse of the population. That malarial disease may be propagated by means of mountain streams, has been often demonstrated, in the many cases of "mountain fever." The generally accepted cause of "chills and fever," has been the decomposition of organic matter in the soil, without any consideration of the fact that these same materials were washed into the brooks. In fact, in all malarious countries, the chief source has been found in the water from streams and wells. And the prevalence and character of these fevers, has always been in proportion to the amount of impurities contained in the water supply, rather than from the exhalations from miasmatic soil.

Dr. D. F. Wright, of the Tenn. Board of Health (in *Sanitary Era)* thus explains the cause of malaria in these so highly esteemed mountain streams. "The *mountains of the* Southern Apalachian System are *densely covered with* vegetation up to the summit.

The density of this vegetation is exceptional; it consists of a grass which is too tangled and matted a growth to be mown, though it furnishes good grazing; each year's crop of this grass grows on a mat of dead grass of the former year; this process going on for years, has established a thick, deep turf, almost wholly consisting of vegetable substance. The same may be said of the mosses, ferns, and dwarf shrubbery, which occupy nearly all the space not covered by the balsam and spruce forests; the consequence is that on the very summit of Roane Mountain and other heights of the system there is a depth of vegetable soil and a mass of decaying organic matter only comparable to that found in the Mississippi swamps. Add to this that an exceptionally moist atmosphere and abundant rainfall, both promote the decomposition, and rapidly carry away its products, so that, while material for malaria is constantly generated, it does not produce its effects there, but in the valleys to which it is rapidly carried off by the rills and rivulets which everywhere rush down the steep slopes of the mountains.

"Thus it comes about that the decay of vegetation on the mountain-tops produces malarious effects, not at the summit, where it is engendered (the constant rains carry it away too fast, but, exhales its baleful influence in the valleys on its arrival there.")

That typhoid fever and cholera may be transmitted by means of drinking water has been abundantly proven by the ablest investigators in this country and Europe. Thousands of published cases, whose origin is beyond question, has established that all rivers o brooks in the vicinity of towns or cities, are contaminated by sewage.

Wolfhugel has examined the potable waters of Berlin for bacteria. The waters of the Agnædur from Stranlan, contained from 1,000 to 5,000 bacteria; after filtering, however, only from 20 to 70. That from Tegel showed from 1,000 to 120, after filtering only from 20 to 40. The pump or ground water of Berlin was found to contain many more bacteria, the number of which amounted in one case *about 12,000* individuals.

At Paris, water is distributed to the inhabitants from several sources. The Dhuys and the Vanne give good pure water, but the Marne, the Seine, and the canal del' Ourcq supply at certain seasons the insufficiency of the water from these sources. But the rivers and the canal are polluted from the dejections of dwellers on their banks, and from the sailors, before their entry into Paris. There is a notable difference in the health of the people from the usage of the waters from these sources, in the increase of typhoid fever. The statistics given are sufficiently eloquent. In 1886 they were obliged to supply a deficiency from these sources by the 10th of July. During the week of 18th and 24th, there entered forty persons in the hospital with typhoid. From the 1st to the 7th of August there entered 150. On cessation of the distribution of the water on the 7th, the disease declined, and from the 15 to 21st there entered only 80 sick. In 1887, on the 27th of January, the water of the Seine and l'Ourcq was again distributed. From the 13th to the 19th of February the hospital received 80 sick. The distribution continued during the months of July and August, during which time there entered 154 sick. It is easy to see the influence of water among a population having the same habits and modes of life. The guards of Paris are distributed in different barracks. The number of cases of typhoid indicates the origin of the disease from the potable water. A new barrack was erected, after the plan of Chateau-Landon, and the percentage of deaths was 17. The guards drank the unfiltered water of the Marne. At the caserne of Jean Jaques Rosseau, the guards drank the water of the Vanne, and the mortality was but 7 per cent. On substituting the water of the Vanne, for that of the Marne in Chateau-Landon, the mortality fell to 2 per cent. Two other barracks paid a tribute to the typhoid fever from the use of the water of the Seine.

"In 1870 the Royal Commissioners reporting on the pollution of the Mersey, and the Ribble, stated that sewage disharged in running water is not materially *changed for many* hours by oxidation.' This they *demonstrated by the* following experiment: a volume

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of filtered sewage from a drain of London was mixed with nine parts of pure water. Analysis of this mixture showed it to contain per 100,000 parts 267 parts of carbonaceous matter. It was exposed each day to light and air, shaken, and drawn by small siphons in a manner to cause a fall of over three feet from vessel to vessel. At the end of 96 hours there remained 250 parts of carbonaceous matter, and .58 parts of nitrogenous matter, indicating a loss of but 17 parts of carbonaceous matter and .23 parts of nitrogenous matter. At the end of 192 hours it had lost but 25 per cent. of carbonaceous matter and 33⅓ per cent. of nitrogenous matter. This experiment was made in a temperature of 68° F., and designed to show the change likely to take place in the current of a river running at the rate of one mile per hour, in carrying ten per cent of sewage. They concluded there was not a river in England long enough to dispose of a moderate amount of sewage through oxidation.

"S. Babut de Maris says, it has been proved that the waters of rivers do not lose a material amount of azote in a run of over three hundred miles. And the Prussian Government has consequently forbidden the pollution of rivers and sea-ports by the discharge of detritus of the cities."

The fact is that human excrement, and the refuse from dwellings, washed into the brooks and rivers, are the chief sources of disease. Though the methods by which streams and rivers become infected, may, in some cases be hard to trace, yet enough proof has been collected to establish the fact.

The great scourges which have decimated the world have been invariably connected with a bad water supply. We have only to refer to a few. Madrid, in Spain, suffered severely in 1865 from cholera. The majority of cases occurred along the banks of the Manzanares and on the Tagus. Below Madrid, is Aranjuez, and still further Toledo. Both take their water from the river. At Aranjuez, the cholera devastated the city, but at Toledo the Governor stopped the supply from the river, and very few cases occurred. At Granada the water from the Genil and *Darro* is carried in open canals, where filth of every

kind finds lodgement. The cholera spread with fearful activity, resulting in two months, in 5,000 deaths.

Valencia, is, for a Spanish town, fairly drained and clean, though less so than Seville. Starting from Alicante, in 1884, the cholera reached Jativa, a town on one of the affluents of the Jucar, which with the Turia, waters the plain of Huerto, that is, the Garden of Valencia. In the spring of 1885, the disease, which had been dormant during the winter, broke out afresh, and traveled down the rivers, attacking the various towns on their banks. At Alcira, it was especially severe, but ceased immediately when the inhabitants discontinued the use of the river water, and had recourse to a spring at some distance from the town. Following the network of canals it reached the Turia, and in the middle of May it burst out in the city of Valencia. At one time, in June, the cases numbered 700 daily, and by the end of September, when it subsided, 4,234 persons, according to official reports, had been attacked, out of a population of 144,000.

We thus see that the sanitary conditions of the various towns, being equally bad, made very little difference, the incidence of the disease being everywhere in direct relation to the water supply. Where the water was good, the disease was slight or even absent, where the water supply was polluted by the choleraic excreta of the neighboring population, the epidemic was severely felt; and. most striking of all, at Toledo, where the unsanitary conditions and filthy state of the town, at the best of times, could not but have been intensified by the deprivation of the sources of supply, the compulsory employment of a pure water, though scarcely more than was absolutely necessary for drinking purposes, had the effect of completely averting the pestilence.

Dr. John Trumbull in the *Medical Record* speaks of the mode by which cholera found its way into Chili in spite of all the precautions taken to prevent its entrance. A cattle dealer, a fugitive from the Argentine Republic, remained concealed for a short time at *Santa Maria* on account of sickness. Five days later *the disease broke* out in that village.

"*The water* was the carrier of the infection. In

Chili, artificial irrigation is relied upon in agriculture, and the river water is carried through small canals traversing the valleys in every direction, and furnishing the supply needed for drinking, cooking, and bathing. The canals then act as sewers, the water-closets being built over them; are next used for purposes of irrigation; and finally empty again into the river. It was along the banks of the canals carrying the waste matter from the village of Santa Maria that the disease disclosed itself. After that, a section of country miles away, but on the banks of the same river, and drawing its water supply from this source, was invaded from the district supplied by the Aconcagua River."

ICE.

It would naturally be supposed that water in freezing would destroy the life of any organisms in it. The contrary, however, has been proven a fallacy, by the researches of investigators. Dr. Cartaz, a French physician published in La Nature a paper on the "purity of ice," from which we abstract the following:

"The lakes of Savoy furnish a very beautiful ice which, for many reasons, ought to be preferred to ice gathered in the neighborhood of large cities. This ice, gathered in the inexhaustible stores of the great mountains, is very pure natural ice. This is not the case with ice gathered in the rivers, or at least in certain rivers and in certain ponds. Let a sewer have its discharge in them, let the water-course form more or less the dumping place for the impurities of a city, this water will be contaminated, and it is not hard to understand that a piece of ice, made of impure water or taken in a sheet of water vitiated by organic matter, will hold imprisoned in its crystalline and transparent mass all the putrid or insalubrious germs of the water itself. The truth of this fact has been emphatically acknowledged in a bill drafted some years ago by the Sanitary Board of the State of Connecticut, which contained the following paragraph: "Any person who, for the use of families or hotels, sells or offers for sale ice cut or taken in a pond or in a place where a sewer of any description discharges, or in a river at a point less than two miles below the

place where a sewer discharges, is liable to a fine of fifty dollars." I remember that formerly, in Lyons, at a time when these paramount questions of hygiene had not been stirred up yet, the ice used to be gathered in the ditches surrounding the fortifications or in the stagnant puddles, the "lones," of the La Guillotiere and La Mouche districts." But what then is the danger that could be caused by ice, besides inconveniences in cases of delicate intestines and of absorption in too large quantities? The danger is that ice contains the same mischievous germs as the water from which it is produced; and although in a lesser degree, yet it does contain them. And the opinion entertained at other times that the degree of refrigeration necessary to produce congelation would by itself cause the death of micro-organisms, was an erroneous opinion. Different experimenters, Cramer, Leone, Gardiner, Fraenkel, have demonstrated it exclusively. Very lately Dr. Mitchell Prudden, of New York, has taken up these researches on a grand scale in the laboratory of the Medical College, taking the view of the sanitary conditions of the city. Artificial ice, which is recommended hygienically as being superior to natural ice, will not actually possess this quality unless it has been manufactured from water that was perfect in all respects. Let the distribution of such be assured, let ice be gathered always in good conditions, and we may drink without danger "*a la fraiche*," as the vendors call it.

We quote some of the conclusions arrived at by the experimenters:

"We are enabled to detect with great certainty the presence of bacteria, some species of which can give rise to serious disease, and that the chemical analysis alone does not suffice in cases in which such organism may be present."

"The popular impression that water purifies itself in freezing is only partly true. While some gross particles, and to a certain extent materials in solution may be largely removed, the bacteria which are the *most* important, if not the sole agents in water *deleterous to health*, are only in part destroyed by the *act of freezing*."

"Different species of bacteria possess different degrees of vulnerability to the action of low temperatures; in some species nearly all the individuals are killed by prolonged freezing in water, while in other species a small proportion only is destroyed, and between these extremes are other species possessing intermediate degrees of resisting power."

"Certain species of bacteria which are capable of producing serious and even fatal diseases in men—the bacillus of typhoid fever and the common bacterium of supperation—are capable of resisting a prolonged exposure to a low temperature with the destruction of a part only of the individuals thus exposed."

In the United States the attention of the medical profession seems not to have been directed to impure ice as a possible source of disease till 1875, when a mild but well marked epidemic occurred at Rye Beach, N. H., which was very thoroughly investigated by Dr. A. H. Nichols, of Boston, and the results fully reported to the State Board of Health of Massachusetts. The proof was unusually conclusive that the epidemic disturbance of the digestive organs was due to ice cut from a shallow pond containing a large amount of decomposing organic matter.

In the American Journal of Medical Sciences, January, 1878, Dr. C. Smart, Assistant Surgeon U. S. A., published the results of a most interesting investigation on "Mountain Fever and Malarious Water," in which he traced the origin of Mountain Fever to the melting snow water in the Rocky Mountain streams and inferred that the germs of this typo-malarial fever were brought down from the atmosphere by the snow, and remaining frozen during the winter, passed into the streams with the melting snow in May, June and early July.

In 1879, an epidemic of dysentery occurred in the village of Washington, Conn., which was investigated by Dr. Orlando Brown, of Litchfield, and Dr. J. H. Reymond, of Brooklyn. The ice used by the persons attacked was from a small and much polluted stream. The *analysis* of the ice itself showed it to be grossly *contaminated*. No other origin being found for the

epidemic, which was limited to those who used the impure ice, the ice was pronounced to be the cause of the dysentery. The case was reported by the State Board of Health of Connecticut.

In the report of the Connecticut Board for 1882, an isolated case of typhoid is reported, where a private ice supply was cut from a pond which had received through a drain the dejecta of a typhoid patient. The Report of the Connecticut State Board of Health for 1880, stated that several isolated cases of enteric trouble and one death were reported during that year, as due to free use of sewage-polluted ice.—*Report of James T. Gardiner in San. Era.*

Prof. Leidy reports finding in ice used for domestic purposes, "worms, immature *anguillules*, and a number of *rotifer-vulgaria—all living.*

Snow and ice do not kill the germs of diphtheria, no more than they do the seeds of grasses or grains. If a large amount of filth has been left under the snow it will come to the surface again in January or the spring thaws, and develope disease.

SAN FRANCISCO.

The study of the actual contents of the water supply of our own city, and its comparison with that in other cities, with the best method of its thorough purification, are matters that vitally concern the health of our population. In order to demonstrate the existence of micro organisms and the different species, we have made many plate cultures during the past three months and present them to our readers.

PLATE I.

The vegetable organisms figured in this plate belong chiefly to the family of *Desmids*, and the sub order *Pediastræ*. They can hardly be said to be injurious since they perform for the water, the same office that plants do for the atmosphere. They absorb decaying matter and give out oxygen. Of their mode of origin there is the same uncertainty that pertains to all microscopic specks of living matter. Dr. Gros says of the origin of Desmids and Diatoms as follows (p. 339):

All that is at present known concerning the modes of reproduction of Desmids and Diatoms is wholly inadequate to account for their sudden appearances in great numbers in situations where they did not previously exist.

In 1845 we had already determined the vegeto-animal origin of the Bacillaria and Naviculæ. As for the last, they make their appearance in diverse shapes. They seem to come from the subdivision of Englenæ, and take appropriate forms, or they are the product of the resolution of Conferves, diverse in the individualization of their vesicles. The Gromes, which resolve the contents of their shell; the mosses and other vegetables which possess a sort of closterian vegetation, and the nodules of vigorous confervœ, that take artistic forms; sometimes as individual vesicles, sometimes free, and sometimes leathery (en aigrettes).

As to the Bacillaria (without pretending that in any one instance they assume all the possible evolutions), they seem to be the product of the englenean confervœ (that is, confervœ which have taken origin from the subdivisions of englenœ). As to the nodules, they divide, and form a long chain, which divides again, and increases until the frustules detatch themselves. We may say, indeed, that in no one circumstance do Naviculœ or Bacillaria, or Closteria, or Diatoms reproduce themselves with entire parental forms (except by a process of fission), but that these organisms are in effect the division of other organisms, which make the end of a series of vital processes and rarely forms of transition (Micrasterias, Arthro, desmus, etc).

PLATES II. AND III.

The diatoms, sponges, etc.; in the second plate are mostly innocent, as well as those in the third, excepting Nos. 16 and 17, which belong to the *bacteria*, that dangerous class of germ life, of which we have before spoken, and to which many of our worst forms of disease owe their origin. It is true as we have said, that many species of this class are quite harmless, *but it is also* true, that even the microscope fails to

distinguish them from those that are baneful.

To discover a certain germ, that performs a certain work, among thousands of like form is no easy task. Many of them, although very much unlike in character, are so closely alike in shape, that their differentration is almost impossible. The only method yet devised is to cultivate them in separate tubes of gelatine, when the shape, color, and method of growth, determines the species. Some will grow in acid, some in neutral or alkaline solutions, when their life history may be studied.

PLATE IV.

The figures in this plate consist of harmless infusoria, met with in all pond or lake waters, and sometimes in wells, scarcely ever found in running streams. The questions which relate to their origin and development await future investigation for their solution. They do not in reality form any of the so-called impurities.

The conflicting opinions of naturalists concerning the degree of relationship existing between Algœ Pediastrœ and Desmids, are sufficient to show the close alliance of these various forms. Pritchard says in his History of Infusoria (p. 30), "Ralfs followed Ehrenberg, Meneghini and others in placing the Pediastriœ among Desmids, but Corda, Nageli, and Braun, have separated the two as distinct group, and in this has the support of Braun. These discrepances of opinion are not difficult to understand, if we bear in mind the absence of any real ground of distinguishing the different forms, one from the other, since the kinships is so close. The only conclusion possible is that they are the products of the developmental unfolding of the same primary bodies of living matter.

In sixteen plate cultures on gelatine, of the organisms contained in Spring Valley water, the number of colonies varied in different cases, from eight to one hundred and five per cubic centimetre, with average of forty-eight and four-elevenths for the series. This is not bad, as the rule formulated on the experience of the German bacteriologists is that a good drinking water may contain as many as fifty bacteria

in a cubic centimetre.* The quality of the water,

* Med. Rec., March 26, 1887, p. 343.

however, depends much more on the species present, than upon the number of individuals; even the slightest contamination with real disease germs rendering it dangerous. Fortunately most kinds are harmless. In thirty-two analyses of the Croton water, made by Dr. Prudden of New York, the number of colonies obtained from a cubic centimetre of water varied from fifty-seven to nineteen hundred and fifty, the average being 243. These examinations were made in October, November and December, and as they varied from month to month, it is hardly fair to compare their result with that of the present series on Spring Valley water which varied much less, being all made in the month of September. The water of Munich, Bavaria, a city where typhoid fever is almost always present, was found by Leone to contain sometimes as low as five bacteria in a cubic centimetre.†

† Ibed, p. 342.

Dr. Prudden, in the article in which he mentions his analyses of Croton water, gives incidentally the figures found in water from other sources, which are repeated here for purposes of comparison. Thus he found in water from Van Courtland pond from 732 to 2,621 per cubic centimetre; in that from Hudson River off Kingston point, from 720 to 3,448. The article was written mainly to give the results of an extended examination of the bacteria present in the ice supply of New York city. The result of 270 complete analyses of specimens of ice gave an average of 2,033 bacteria per cubic centimetre, showing that the ice is more then eight times as impure as the Croton water itself.

Washington, D. C., derives its main water supply from the Potomac river. Examinations made at the Agricultural Department by Mr. Theobald Smith, showed from 3,459 germs in March, to 4,228 in January, per centimetre, the average of ten analyses giving 3,284.*

* Sanitary Era, August 14, 1886.

The following table gives the number of germs in a *cubic centimeter* (1-1,500th of a pint) of Potomac

water drawn from a faucet in the basement of the Agricultural Department. This water is running constantly, so that it furnishes a fair sample for analysis:

Jan. 8, 1886. -	3,221 germs.	Very turbid
" 11. - - -	4,228 "	" "
Feb. 4. - - -	3,151 "	" "
" 8. - - -	1,997 "	
" 15. - - -	3,225 "	" "
" 22. - - -	1,772 "	
March 2 - - -	3,459 "	" "
" 10 - - -	1,069 "	
" 16 - - -	380 "	Quite clear.
" 18 - - -	338 "	" "

From this table it will be seen that the comparatively clear water yielded only a small number of bacteria. This is quite sufficient; it indicates that the suspended matters were the bearers of the bacteria. If it contained much organic matter in solution—if it were a bad water in other words—the bacteria would still be found in large numbers, even in clear water. Hence, filteration will effect a perfect sanitation of the Potomac water.

An analysis of *clear* water from one of the city wells, March 9, showed 3,162 germs per cubic centimeter: worse than the average of the dirty Potomac!

The water of the Thames river has long been used for the supply of the city of London. The intake in 1581 was at London Bridge, to which others were added, viz, at Charing Cross, in 1691; at Chelsea in 1723, and at Lambeth in 1785. Filtration through sand-beds began in 1829, and in 1852 an act of Parliament decreed that water should be drawn from the river only above Teddington Lock, beyond the influence of the tides. Other sources of supply for London are found in the river Lee, and in springs and wells in the chalk formation. Dr. Frankland reports during the present year that Thames water yielded 4,800 colonies of bacteria per cubic centimetre, before *filtration, and* but from 10 to 50 after. The water *from the chalk* wells gave but eight at the wells,

which had increased to 101 at the reservoirs in London.*

* Lecture before Franklin Institute by Dr. Albert R. Leeds, published in *The Sanitarian*, July, 1886.

These observations when tabulated give a fair idea of the comparative purity of the Spring Valley water. In cases where the sources of information do not give the number of analyses, nor their average, the numbers given have been placed in the average column with a question mark.

SOURCE.	Analyst.	No. of Bacteria Per C. C. Rec.			Number of Anal.
		Minimum.	Maximum.	Average.	
1. Munich	Levice	5.	.....	5?	10
2. Dhalkwells, near London	Frankland.	8.	.....	8?	8
3. Filtered Thames Water, London	Frankland.	19.	105.	48 4-11	16
4. Spring Valley, San Francisco, Sept.	Hopkins	.....	59.	39?	16
5, Chalk Water Reservoir, London	Frankland.	101.	.....	101?	8
6. Croton Water, New York	Preeddess	57.	1950.	243	32
7. Van Cordland Pond, N. Y.	Ditto	732.	2621.	1676?	20
8. Ice Supply of New York	Ditto	.....	.....	2.033	270
9. Hudson River off Kingston Point	Ditto	720.	3448.	2.048?	30
10. Potomac Water, Washington	Mr. Theobald Smith	338,	4228.	2284	10
11. Unfiltered Thames Water, London	Frankland.	4800.	.....	4800?	40

This table speaks well for the good quality of Spring Valley water. In its natural state it is almost equal to filtered Thames water, and though worse than the product of the wells in the chalk region of Kent, is twice as pure as that becomes when stored in a reservoir for use. Croton water at its purest is worse, and five times as bad on the average during the fall and winter months. How Washingtonians can use Potomac water at all without purification, is a mystery, containing as it does almost forty-eight times the number of bacteria that San Francisco water does. The single observation of Leone on the water in use at Munich is too little to prove the comparative merit of that supply. Bacteria are apt to form clouds in the water with nearly clear spaces between, and only an extended series of observations can give a reliable

basis for forming an opinion as to their numbers. Like other vegetable matter these organism multiply. especially at certain seasons of the year; and experiments should be made in each month to be conclusive. In fact, the rank here given to the Spring Valley water may be entirely altered by analyses made in other months.

Materials are not at hand for any very extensive comparison of the larger forms present in our water supply with those imbibed by the citizens of other places, but a couple of plates are presented showing the results of a study of the Croton water at New York by John Michels, the microscopist. The first of these presents four circles, three from the Croton water, while the fourth being the lowest circle on the right hand, represents the contents of Lake Erie water, drawn by C. M. Vorce of Cleveland, Ohio. The latter consisting mainly of innocent infusoria, need not detain us long. If Clevelanders drink lake water and it contains nothing worse than these specimens, they are exceptionally fortunate. But, as in the case of the Munich supply, the information at hand is too meager for comparison. With regard to the Croton water the figures given are more satisfactory. The left hand upper circle shows a crowd of diatoms and desmids, very similar to those in the first two plates from Spring Valley water. Amongst them the Ceratium (No. 14, Plate II) may be easily recognized with the star-like forms of species of Pediastrum. These are harmless, but in the right hand upper circle, besides the Cyclops or water flea, of which there are two specimens, one seen in profile; the Ergulus, the large ten-legged creature on the left, and others which are innocent, these are small rounded bodies with granulated centers. These are the eggs of the Taenia solium or tapeworm, which, if swallowed, will infest the drinker with that dreaded parasite. Still worse, where these are found we may naturally expect to discover the eggs of its congener, the tænia echinococcus, or tapeworm of the dog, which in man causes hydatids in the liver and other organs, proving generally fatal, of which we have spoken.

The ugly specimen at the bottom of the circle, of

which an enlarged view is given in the lower left-hand division, is said by Mr. Michels to be foreign to the water, so that it is always found dead and decaying, but it is present in great numbers so as to give a horrible taste to the water. Fortunately it makes its appearance for only a few weeks at a time.

See "Croton Water" Plate.

Here we have again the eggs of internal parasites, Nos. 54 and 55, with a large number of infusoria, comparable mostly to the ten specimens in the fourth plate from Spring Valley water. If Mr. Michels had named all the diatoms and desmids figured in the left-hand upper circle of his first plate, his list would have far outnumbered my own. Surely, taken in connection with Dr. Prudden's research on the same water, showing it to contain, besides all these larger organisms, 243,000 bacteria per litre, on the average, we can have no difficulty in admitting that New York ought to purify her water supply.

The records of the New York Board of Health show that the filth from slaughter-houses, dairy and horse stables, and from 1,879 country privies, is constantly flowing into the Croton River, above the intake of the aqueduct that supplies New York.* This, no doubt,

*Medical Record, Feb. 27, 1886, p. 249.

explains the condition of the water. But it also contains a warning for us, that as population increases around lakes Merced and Pilarcitos, so may we expect the Spring Valley water to approach more and more nearly to the condition of the Croton. This gives us a practical interest in the third branch of our subject, viz: the consideration of the means employed in other cities for purifying water. The first of these is

FILTRATION.

Dr. Koch of Berlin, with Professor Frankland and Dr. Bischof, of England, have made a great number of highly interesting and instructive experiments on the germ culture of water and in determing the proportion of these micro-organisms that can be eliminated in various ways; by filtration through different *media*, by agitation with solid particles, by chemical *precipitation*, and by natural agencies. Dr. Frank

land's results and conclusions are given in the December number of the *Journal* of the Society of Chemical Industry for 1885.

From this report the following conclusions are to be drawn in regard to filtration:

1. It is possible by a proper filtration to entirely deprive water of its germ life.

2. After complete deprivation of its germ life, if water is exposed to the ordinary influence of air and contact with the biologically unclean materials used for its storage and conveyance, the germ life is rapidly reintroduced and multiplied.

This makes it desirable to furnish the filtered water for use as soon after the operation as practicable.

3. It is necessary to renew or clease the filtering material very frequently. In some cases the water filtered through materials which had been in use for a month had its germ life increased by the operation.

4. Some materials, which exert but an insignificant chemical action, are completely successful in purifying the water, from a biological point of view. This is the case with powdered coke and charcoal.

At a recent meeting of the German Congress of Naturalists and Physicians, Dr. Plagge read a memoir on the filtration of water, starting from the axiom that the essential task of filtration is to free water from infectious matters, consisting chiefly of bacteria. The distinction of the bacteria into pathogenous and non-pathogenous is here unimportant, since a process which allows the non-pathogenous germs to pass will not keep back those which are pathogenous, while on the other hand, we are justified in assuming that one that keeps back all other bacteria will give protection against infectious matters. Since no practicable "coagulant" of bacteria in a direct sense has been discovered, we are obliged to rely mainly on coagulating for filtration the organic matter in which bacteria are bred and nourished, and subsequently sterilizing any scattered germs by profuse oxidization under pressure. The simply mechanical process of filtration, at best, is available only for small quantities of water, and with frequent renewal or roasting of materials.

Most of the ordinary domestic filters, even those

of spongy iron, carbon, stone, and cellulose, do not, according to Dr. Plagge's observations, come up to the above requirement of arresting germs. On the contrary, there is generally found a marked increase of organisms in the filtering material after a time. Experiments made with pure cultures of typhus and cholera prove that such filters allow these infectious matters to pass without hindrance. Better results were obtained with clay and asbestos filters of different constructions (Chamberland, Breyer, Olschewsky, Arnold and Schirmer), as for a certain time they yielded water free from germs. However, it was not practicable with any of these apparatus to obtain water perfectly free from microbia for a long time. According to Hesse, asbestos strongly compressed, and especially dense cells of clay, form a filtering material which yields water permanently germ free.

German opinion on purification of city sewerage or, as they call it, "canal-water," has been fully and authoritatively stated in a recent general meeting of the "*Niederheinishe Verein fur Offentliche Gesundheitspflege,*" held at Elberfeld, in Prussia. *Flushing* seems to be the prevailing system in all cities of any importance, for the elimination of refuse and fecal matters. But the purification of the waters thus impregnated is carried on under different methods. The use of them for *irrigation* (meaning for agricultural purposes) is considered the best method, but the number of cities, favored by the necessary local and financial conditions, where it has been introduced, is very limited. Berlin, Danzig, Breslau, especially Bunzlau in Silesia, where sewer farming has existed for centuries, are the principal cities enjoying this system. In Bunzlau, it is an ancient municipal institution, the successive use of this kind of irrigation on the different rural properties being regulated in a legal manner, as shown by the city records. In recent times, the cities of Oswitz and Ransern have introduced the irrigation system and were mentioned, a year ago, by the German Association of Public Hygiene for the excellent results obtained by them.

Simple *filtration* by the soil or other material is *the second* method employed, though considered in-

ferior, and only in places where irrigation (sewer farming) was of difficult introduction.

Where neither irrigation nor filtration were practicable, the so-called *combined method* of *mechanical and chemical* action is resorted to. The "clarification establishments" of Frankfort a. M., Wiesbaden, Essen and Halle a. d. Saale, are prominent, and engage the attention of professional men.

The Germans attribute the superiority of *irrigation*, or sewer farming, to a combination of the following three effects:

1. The suspended muddy substances are precipitated in and on the soil.

2. The organic substances in solution are either partly absorbed or partly destroyed by direct decomposition and oxydation, the carbonic, sulphuric and azotic combinations passing into the corresponding oxygenate combinations, that is to say: Carbonic acid, sulphuric acid and nitric acid. At the same time, the irrigation water, being spread out on a large surface, is brought into intimate contact with the atmospheric air, absorbing from it a new supply of oxygen.

3. The dissolved mineral substances, or mineralized combinations, as nitric acid, sulphuric acid, etc., are decreased in quantity, being either assimilated by the plants, cultivated on the area, or absorbed in lesser proportion by the soil, as potassa, ammonia and phosphoric acid.

It was in earlier years, generally admitted, that the purification of sewerage by the soil was eminently a precipitation of the impurities contained in it, not only mechanically, but at the same time chemically; in a word, an absorption. This is true in a certain way; for the bases present in the soil, as oxyd of iron, alumina, carbonate of lime, as well as silicates and other oxids have a chemical action on acids, bases and coloring matters contained in the sewerage liquids, taking hold of them through chemical transformation. Yet, this transformation or absorption, is of secondary importance, when compared with the other *agents of purification*. As we have said before, *micro-organisms* are an important agent for the

transformation of complicated azotic combinations, first into ammonia, and then, through transformation of the latter, into nitric acid. Lately, it has been demonstrated that even the formation of carbonic acid, heretofore attributed exclusively to direct oxydation by the oxygen of the atmospheric air, is eminently due to the vital activity of micro-organisms. But all these products of transformation and oxydation, due to micro-organisms, are rather absorbed in a direct way by the plants themselves, than by the soil.

The principal defects found by the Germans in the irrigation system are:

1. The soil, or the vegetation grown on it, is limited in its effect, as to the destruction of sewerage substances, to 60–80 inhabitants per ha (1 hectare=2.471 acres). This quantity of sewerage substances contains as much nitrogen as, under the most favorable circumstances, the soil could possibly be deprived of by the crops. On the other hand, the number of inhabitants, corresponding to 1 ha of the area of irrigation, is generally much larger than 60–80: It is in Berlin 270, in English cities 200–300, so that in these cases the soil, in course of time, will be overloaded with organic matter, the result being contamination of the subsoil water, just as in the cities. In this case, there is no suppression, only translation of the evil.

2. In irrigation with city sewerage, it is to be considered that the alimentary substances for plants, contained in the water, are present in other proportions than those available by agricultural plants. Thus, for each 100 parts of nitrogen, there are present:

	Phosph. Ac.	Pot.	Lime.	Magnes.	Sulph. Ac.	Chlorine
In sewerage water.....	26	45	120	25	30	125
In agricultural plants..	48	140	49	22	18	55

It is evident from this table that city sewerage does not constitute a perfect solution of nutritious matter for the plants, and that it is necessary, in order fully to exhaust nitrogen, to provide the soil at the same time with phosphoric acid and potassa.

3. *In countries, that are subject to frequent frosts in winter,* the irrigation system meets with a special *difficulty* in the impossibility of disposing of the

ferior, and only in places where irrigation (sewer farming) was of difficult introduction.

Where neither irrigation nor filtration were practicable, the so-called *combined method* of *mechanical and chemical* action is resorted to. The "clarification establishments" of Frankfort a. M., Wiesbaden, Essen and Halle a. d. Saale, are prominent, and engage the attention of professional men.

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by means of extreme æration, which also oxidizes, or consumes, any still lingering remains of organic corruption.

For the lower animals a less perfect purification of water is provided, through its evaporation and re-condensation in rain, supplemented by the comparatively superficial æration of streams. But the safety of man is a more delicate and important matter, and for this the complex and elaborate process above outlined is constantly, universally, carried on under ground. Every drop of true spring or well water in the world has been put through the whole of this three-fold process. And wherever the human water supply has to be derived from streams, or from wells and spring that are exposed to any possible contamination with organic or other filth, it is imperative, for human health and safety, to reproduce and apply artificially the same process in which nature has instructed us.

(1.) To extract the subtle and dangerous corruptions that are held in solution. No mechanical means can get the slightest hold on these perfectly invisible and intangible elements in water. Only an agent of chemical affinity can seize upon these occult poisons, forcing new combinations that change their character from soluble to insoluble, and so coagulate some and precipitate others in flakes distinct from the water and capable of being strained out from it. This preparation is effected by the action of the abundant earthy salts—sulphates, carbonates, etc., of alumina, potassa, lime and iron oxide—that are everywhere distributed through the soil for this purpose. Patient observation and experiment have evolved the method and mechanism for injecting artificially the proper minute proportion of the proper salt for the preparation of any water, according to its peculiarities, and in such a manner as to pervade the water uniformly and instantly on the largest scale required. (Half a grain of alumina-potassa sulphate, or alum, is about an average dose per gallon for the fine and soluble impurities of river water.)

(2.) Having thus cast the soluble impurities into *new and tangible* combinations with the chemical

agent, the combined substances are to be strained out by a powerfully compacted bed of fine sand. The vast scale on which this is done by nature, at great depths and under great pressure, is a fact familiar to every one. The pressure is imitated on a bed of fine selected sand and ground-coke, from five to eight feet deep, by means of an initial head of water, natural or artificial as the case may be, which forces the bed into closer compactness the faster it forces the water through it, leaving the coagulated impurities behind, as well as the coarser palpable sediment.

(3.) The impurities caught in the filter must be constantly romoved, or it becomes a storage of filth for the worse contamination of the water passing through it. Nature does this by the nutritive organs of the plants. Man does it by frequently reversing the water pressure, which boils up the whole mass of sand into liquid suspension, and keeps it in violent agitation or attrition, until the water rushing through it and overflowing at a sufficient height has washed away every foreign particle with which the clean sand had been soiled, and runs off perfectly clear. The water pressure is then again turned downward and soon compacts the filter bed as before.

(4.) The extreme æration by which nature finishes the perfect water intended for man, is accomplished by the extreme pressure of the atmosphere in the depths of her filter beds; the effect of which is to multiply marvellously the proportions of oxygen absorbed in the interstices of the water, and apply the full power of oxygen to consume corruption and to deprive organic germs of their pernicious fecundity in the veins of man; the same power utilized by Pasteur and all other inoculators against malignant diseases. This pressure is imitated artificially, by causing air to be injected into the filter and the water mains by the force of the head of the water, so copiously that the water is wholly converted into milk-white foam, with much more air than water in the mixture, as it issues from the pipes. The water after being released still remains charged with all the oxygen it can carry under the ordinary atmospheric pressure; and this complement of oxygen has bee

found by Prof. Austen to operate for a month with marvellous potency, reducing practically to nothing the small trace of impurity still left in the water after the filtration and æration under pressure. This circumstance suggests the utility of drawing off apart the water thus filtered and charged with air, in receptacles where it may stand for a considerable time before using; unlike unpurified water, which grows corrupt and fetid by standing, such water, it is found, only grows more exquisitely pure and sweet from day to day.

The Chelsea Company of London has the honor of having taken the intiative in this matter by the erection of a sand filter-bed, in 1829. The success of this experiment has rendered filtration through sand the favorite device in England, for the cleansing of water. A bed of coarsely broken rock is prepared, covered by several layers of progressively finer material, the whole being cappcd by from two to four feet of sand. The filth is arrested by the upper six inches of sand, so that the occasional removal of this layer and its replacement with fresh sand is all that is required to keep the whole in good working order.

SEDIMENTATION.

Simple settling in large reservoirs has been found to do much toward the cleansing of the water, much organic matter undergoing oxidation, and the larger inorganic material subsiding. But if the water is contaminated with sewage, offal, or human or animal waste of any kind, the sooner it goes into its victims the less harm it will do them, in most cases. To detain it in a settling basin, especially in summer, long enough for even its suspended mineral matter to go to the bottom, is to brew a sort of devil's broth out of the putrescent ingredients, that will grow more poisonous every day it is kept. If any such ingredients should settle, so much the worse. They will rot in the muck at the bottom and enter into direct solution, or generate deadly gases to be absorbed by the water, beneath the reach of oxidation *or any other remedy* provided. In point of fact, it *may be presumed* without exception that every water

supply will deposit enough organic matter to produce in a few months an accumulation of muck. We believe there was never a settling basin drained without finding putrid sediment at the bottom of it. The growth of both animals and plants depending largely upon sunlight, it has also been found advantageous to keep the water after settling and filtration, in covered reservoirs.

These principles have been rigidly adhered to in London since the passage of an Act of Parliament upon the subject in 1852, rendering them legally binding upon the various water companies.

There are now in London 465 acres of subsiding reservoirs, 98 acres sand filter-beds, and 53 covered reservoirs. for keeping the water for distribution.

So successful has this method proved, that, as we have seen when treating of bacteria, Dr. Frankland's report, which appeared in May last, gives 4,000,000 as the number of microbes per litre in unfiltered Thames water, reduced to 19,000 at the Chelsea works (which, although the oldest, appear to be the most successfully conducted), and to 59,000 in those of West Middlesex.

In our own country, this method has been carried out at Poughkeepsie, N. Y., but it has never become common in America. The objections to it are that it is cumbersome, the first cost is large from the great areas required for reservoirs and filter-beds; the action of the beds irregular; free and effectual at first, the water flows more slowly, and is less perfectly cleansed as the sand becomes filled with filth; and finally the expense of renewing acres of sand every few weeks amounts to from $2.50 to $5 per million of gallons filtered. The expense involved naturally compels the companies to avoid renewing the sand as long as possible, and however ideal filtration through sand may be, it becomes in practice for long periods of time, filtration through a seething mass of accumulated nastiness.

American ingenuity has made several attempts to obviate these difficulties, but thus far without success brilliant enough to command extensive adoption of any single plan. Thus in the so-called "National"

filter, the rock work under the sand-bed is replaced by double perforated pipes, having fine quartz gravel filled in between them. What special advantage this may offer is hard to see, as the pipes must cost as much as the rock-work, and the sand still has to be removed as before. In another device, the perforated pipes run six inches below the surface of the sand, and a reverse current introduced through these, washes the dirt away when cleansing becomes needful. This appears to be an advance in the right direction, rendering frequent cleansing easier, but the most that a ssttling basin can do, is to detain fine and other heavy suspended earths. There is no dangerous ingredient in water that will "down at its bidding," nor will it even clear muddy waters well. There is much matter of all kinds that is so fine or light that it will never settle, and much more that, like the cloudy suspension in the river Rhone, requires four months of undisturbed repose to sink.

Settling basins are not cheap. They may be cheaply—and by so much the more worthlessly—constructed, but the cost of maintenance and cleaning will balance the interest on a purifying system that does a real sanitary and beautifying work to the satisfaction and delight of all consumers.

ARTIFICIAL AERATION.

Long as the freshening effect of natural æration upon water has been known and commented upon, it is but recently that it has been tried artificially with a view to the purification of any city supply. This was due to the engineering ability of Albert R. Leeds, Ph. D. The Schuylkill water in use at Philadelphia became very offensive in the winter of 1883. Samples having been submitted to Dr. Leeds for examination, he noticed that they were deficient in oxygen, but contained much free and albuminoid ammonia. The idea occurred to him to try the effect of thorough æration. This, in his laboratory experiment, was to destroy much of the sewage that they contained, and to increase the amount of oxygen. He therefore suggested to the Philadelphia Company that pumping

air under great pressure into the mains would correct the difficulty.

While the matter was under consideration an extraordinary contamination of water took place at Hoboken. A thick scum formed over the reservoir, and drying, resolved itself into green and blue coloring matters, with great evolution of gases, the water becoming extremely offensive to both taste and smell. Examination showing the same deficiency of oxygen as in the former instance, Dr. Leeds again suggested his remedy. This was applied in September, 1886. The amount of oxygen in solution in the water was speedily raised to its proper figure; the impurities were diminished; growth of vegetable matter ceased, and the evil was removed.

Encouraged by this result, the Philadelphia Company tried the experiment in November, 1884, at Fairmount pumping station. An improvement being manifest, the necessary apparatus was put in operation at the Belmont pumping. Prof. Leeds gives the following table to show the effects of his system of æration upon the contents of the water.*

*Sanitarian, July, 1887, p. 28.

	Parts per 100,000.	
	Non ærated.	Aerated.
Free Ammonia	0.017	0.004
Albuminoid Ammonia	0.011	0.007
Oxygen required to oxidize organic substances	0 133	0.117
Nitrous Acid	0.0008	None.
Nitric Acid	0.45	0.54
Total Solids	9.00	8.70

The action of the air in oxidizing nitrogenous impurities, and therefor in depriving the minute forms of vegetable life, including bacteria, of the pabulum on which they thrive, is obvious from these figures. The small amounts of free and albuminoid ammonia remaining are inappreciable to taste and smell. The change of the nitrous into nitric acid, as well as the raising of the percentage of dissolved oxygen in the water offer security against stagnation in the reservoir, with its deleterious results.

Still another proof of the efficacy of this process has been made at the Greenwood Cemetery waterworks in Brooklyn, N. Y. The special contamina-

tion to be removed this time consisted of an unusual multiplication of diatoms, rendering the water nauseous by an accumulation of a greenish vegetable slime. Again, dissolved oxygen was found deficient, and the application of an air compressure, pumping an amount of air equal to one-tenth that of the water into the mains, under a pressure of 80 pounds to the square inch, sufficient to oxidize the food of the diatoms, and the water became bright and clear.

This neat application of science to an important practical purpose deserves attention, not only for its intrinsic merits, but as an important and recent addition by American talent, to a subject that has long been attracting the studious attention of European scientists. That oxygen is one of the most powerful decomposing and disinfecting agents of Nature, is of course unquestioned; but there are many ways to escape its search, of which hiding in deep water is among the most familiar to engineers. To pursue the occulted filth of a river to its depths is impossible to oxygen under the ordinary atmospheric pressure and without ample avenues opened for it throughout the water. The water must be opened throughout to the air, by force, and the air injected under a pressure of several atmospheres, in order to accomplish an effective oxidation of oxidizable impurities; and this process must be a protracted one, in case the impurities are of considerable amount. After coagulating and filtering out the bulk of them, a vigorous oxygenation of the water under pressure, charging it highly as it enters the mains and while it remains there, has been found adequate to dispose of the minute remnants of oxidizable matter, to the best standard of nature-purified springs. At its best, therefore, oxidation is but a finishing process in water.

Another set of means resorted to in Europe as well as in this country for the cleansing of water, is its

CHEMICAL PURIFICATION.

This consists in the addition to unfiltered water of small proportions of chemicals, which have the property of destroying albuminoid matter, or coagulating them, so as to favor their subsequent removal by sub-

sidence and filtration. Among these, alum, lime, iron, carbon, borax, and potassium permanganate are the most important. Of these alum is of the most general application, acting not only as a coagulant of albuminoids, but owing to its property of forming a lake with argillaceous impurities, clarifying the water by precipitation and being precipitated itself in the process. The use of alum to clear muddy water has long been known, but Prof. Leeds, in the course of an investigation on an outbreak of typhoid fever at Mount Holly, N. J., discovered another value in its use which may be very important. He found that the water which was supplied to the inhabitants of Mount Holly was swarming with bacteria, about fifteen drops being capable of forming 8,100 colonies of these microscopic germs when spread upon a suitable surface. He tried the experiment of adding a minute amount of alum to this water in the proportion of only half a grain to a gallon, and found that not only was the dirt and coloring matter precipitated, but that instead of the same quantity of water containing 8,100 colonies of bacteria, it contained only 80, and these were all of a large form. On filtering the water through two thicknesses of filtering paper he found that the filtered water contained no bacteria, but was "as sterile as if it had been subjected to prolonged boiling." This amount of alum is too small to be evident to the taste, and is not harmful to health. If his observations shall remain unrefuted, they may form a valuable method of purifying polluted drinking water. Prof. P. B. Austen (Textile Colorist; *Pharm. Jour. and Trans.*, p. 86, '86), gives a number of experiments instituted to determine the smallest quantity of alum required for the clarification of different kinds of water by precipitation. The information is interesting rather than practical, as precipitation requires so much more alum or other reagents than filtration, and is withal so slow, that it is not to be considered, scarcely even for sewage. Still, the following description is valuable, as showing in exaggerated characters the principle of the chemical treatment of water preparatory *to filtration* (not precipitation,) in Nature and in the

art according to Nature: "City water containing an average of impurities was found to require about two grains of alum to the gallon. Complete separation takes place in the course of six or seven hours, which is hastened by adding the alum in excess. This has the disadvantage, however, of leaving the water contaminated with free alum, or the portion not combined with the impurities. But when the exact amount has been employed, the impurities settle to the bottom, leaving the water perfectly clear and free from any appreciable amount of alum. The kind of alum employed, being a double sulphate of aluminum and potassium, it breaks up into insoluble basic of aluminum sulphate, which precipitates as an insoluble magma, carrying all the organic impurities with it, and the sulphuric acid set free, forms insoluble compounds with the alkaline earths, calcium, etc., mostly always present in waters. According to this reaction only the potassium sulphate remains in solution, and that in minute quantities."

The permanganate of potash is an excellent agent also, destroying organic substances by oxidation, and yielding up its manganese in the inert and tasteless form of binoxide, which subsides, carrying with it a large proportion of the contaminations present. Where a water is highly charged with carbonic acid or the carbonates, lime becomes of especial value, being changed to insoluble chalk, which in settling performs the same office as the others in the mechanical removal of matters too fine to fall to the bottom of the impounding reservoir by their own weight. Prof. Dobroslavine, of St. Petersburg, advises as a good precipitating agent a solution of perchloride of iron followed by a solution of carbonate of soda. Simple and devoid of inherent novelty (says the *Lancet*) as the suggestion is, it is very sensible. Translated into English weights and measures, the quantities used are about three grains of perchloride of iron and four grains of soda crystal per gallon of water. The precipitate is said to settle in about forty-five minutes and to leave the water perfectly clear. The quantity of carbonate of soda is sufficient for the complete decomposition of the

iron salt, but would convert it into a heavy, insoluble basic chloride, which would doubtless snttle easily. Let us see what the iron process is, and what is its history by the representations of its present sponsor, Mr. Anderson. Stated in brief, it is settling-basin filtration of water prepared by the chemical action of iron upon its organic and other soluble contents. These processes are given first as arranged eighteen years ago, by Prof. G. Bischof, and then as modified, from necessity, by Mr. Anderson. Prof. Bischof's filter-bed consisted of a top layer of sand, an intermediate mixture of granular iron and gravel, and a bottom layer of sand. The simple process of settling and straining the water through these materials, Mr. Anderson says, was in use for some time at Antwerp, on a large scale, cleaning the water almost perfectly; but owing to the greatly polluted condition of the river, the iron had an abnormal amount of work to do, and the layer of gravel and iron was quickly choked by the dissolved impurities. The upper layer of sand had to be cleaned about every two weeks, in the usual way; that is, by scraping off and washing or changing the sand.

When this was removed the gravel and iron particles beneath were found thickly coated and mixed with a reddish, slimy substance, to a depth of six or eight inches; while deeper down, "the mixture was of an intense black;" the organic impurities "clogging up a very open mixture of gravel and iron, much too coarse to act as a filter."

These results speak for themselves, and sufficiently account for Mr. Anderson's effort to improve the mechanism; apart from the fact that the inflowing water was twelve hours in reaching and passing through the filter, and issued at the rate of only seventy-five gallons in twenty-four hours, per square foot of filtering surface.

These three principles then, *subsidence*, aided or not by chemical means, *filtration*, and *æration*, lie at the bottom of all attempts to purify a water supply.

It remains to notice the only device that has come under our notice of a system that combines all three of these in due proportion, securing good and uniform

results with scientific accuracy, at only a moderate cost. This is the Hyatt system, also a product of American ingenuity. A brief description of the main features of this system, taken partly from the report of Thomas W. Symons, to the U. S. Senate, under date of March 29, 1886, recommending its employment in cleansing the water of the Potomac for use in our National Capital, will form an appropriate conclusion to this article.

The Hyatt filter consists of a steel cylinder of a capacity suited to the amount of water to be filtered, divided about the middle by a steel diaphram. The filtering material used is coke, and occupies the lower compartment. The upper compartment is used for washing the filtering material, which is done by reversing the current of the water. This is done daily and consumes about two per cent. of the filtered water. The reversed current carries the coke into the upper compartment in a state of violent agitation that ensures the perfect cleansing of every particle, and the removal of all filth deposited in its interstices by the impure water. The cleansed filtering material is then returned to the lower compartment.

These operations are provided for by a system of vertical pipes, extending from near the bottom of the lower part, to the top of the upper chamber, through which pipes the reversed current carries the coke and contained dirt, while there are valves in the diaphragm, permitting the easy return of the cleansed filtering material to its former position in the lower chamber.

Here it rests on the mouths of cups, that are filled with coppor shot, that sustain it in position. The water to be filtered is then introduced into the top of the lower chamber, the valves in the diaphragm and its pipes being closed. The pressure being properly regulated, the filtration proceeds as rapidly as may be desired. The copper cups lead each into its own pipe, which conveys the filtered water to the mains. One excellent result of this filtration under pressure is the complete æration of the water, which issues from the mains as white as the foam of a water-fall, from the presence of minute bubbles of air. The

Sanitarian Era (January 15, 1886,) says: "There is no 'art and mystery' in working the apparatus. It requires no experts nor skilled attendants. It is wholly a work of automatic mechanism; and this automatic simplicity of process obviates all difficulty that might be apprehended in multiplying sets of apparatus or in combining, as more convenient, the capacity of ten 10-foot filters in one 30-foot filter. The depth of filtering material, and height of the chamber, are substantially the same in one of 30-foot diameter as in one of 10-foot. The simplicity of the structures enables them to be made at all points equal in durability to the best water-mains, and equally free from liability to get out of order."

Alum is added in very small proportion to the unfiltered water in the impounding reservoir, so as to coagulate the albuminoids and concentrate the other impurities in a form more easily arrested by the filter.

Thus all the principles that have thus far been elaborated in connection with the subject have received due attention; *subsidence with chemical aid in the reservoir; filtration by a better material than sand*, under conditions that ensure the easy and regular cleansing of the filter bed, and with a pressure that brings about *complete aeration;* the cost of the whole, and its running expenses being small compared with that of the cumbersome English filter bed.

The many advantages of this system have already recommended it to the common sense of many American cities. It is in use in more than twenty places, and unless surpassed by new inventions, bids fair to be employed in many more. The fact that it is protected by patents does not appear to us to render this notice of its merits improper in a medical journal. To point out the need of pure water would be of little practical use, without also showing how it can be obtained. It is to be hoped that some enterprising San Franciscan will speedily improve upon even the Hyatt system, and that our water company will soon grant to the metropolis of the Pacific, a water supply which shall not only be somewhat better than that of New York, but shall be rendered by use of a home invention, *absolutely* pure.

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